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Sympetrum fonscolombii immature male (Selys, 1840) - Italy, Sicily, Trapani: Diga Rubino

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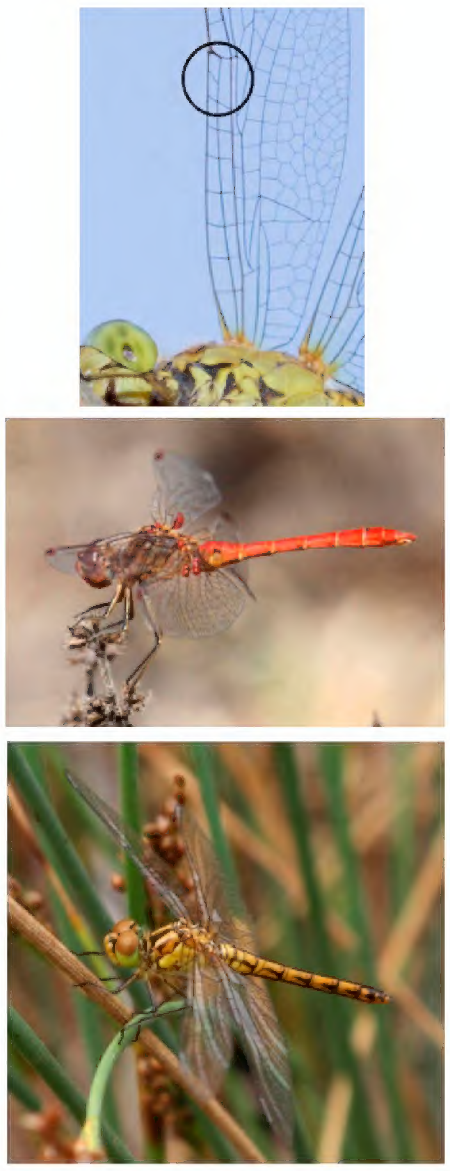
The genus *Sympetrum* Newmann, 1833 (Odonata Libellulidae). *Sympetrum* is a genus of small to medium-sized skimmer dragonflies, known as Darters in the UK and as Meadowhawks in North America. More than 50 species live predominantly in the temperate zone of the Northern Hemisphere; no *Sympetrum* species is native to Australia. This genus is distinguable for many markings. The forewing has a distinctive venation with 6 ½ - 8 ½ antenodal cross veins. The number of antenodal cross-vein (Ax) in the forewing is counted along the anterior wing border between the base and node. The last Ax (closest to the node) is incomplete if only the anterior half is present. The hindwing base are clear or marked with yellow or amber. In Europe, all the species have totally black legs or with a yellow stripe. Only a Turkish species, the Dwarf Darter *S. haritonovi*, has pale tarsi. In the *Sympetrum*, like all Libellulidae and Corduliidae, the acute corner of forewing triangle points backwards. Furthermore, like all Libellulidae and *Anax*, the males do not have anal triangle (a conspicuous triangular field at the hindwing next to the membranule) on the wing. They spend most of their time on perch, from which short sorties are undertaken to chase preys or rivals. Commonly, they are yellow-gold as juveniles and females, with mature males bright red on parts or all of their bodies, with the exception to this scheme color of the Black Darter *S. danae*. Only one species of S*ympetrum* is in the European Red List of Dragonflies with the status Vulnerable (VU), the Spotted Darter *S. Depressiusculum*.



Salvatore Surdo. Department of Agriculture, Food and Forest Sciences, University of Palermo, Viale delle Scienze, Edificio 4, 90128 Palermo, Italy; email: salvatore. surdo@unipa.it (photos S. Surdo, Sicily, Trapani, Diga Rubino; above: the last antenodal cross-vein is incomplete when only the anterior half is present (*S. striolatum*); center: *Sympetrum meridionale* (Selys, 1841) male; below: *Sympetrum striolatum* (Charpentier, 1840).

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Reproduction and growth of Axillary seabream *Pagellus acarne* (Risso, 1827) (Perciformes Sparidae) from the western Algerian coasts

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ABSTRACT *Pagellus acarne* (Risso, 1827) (Perciformes Sparidae) represents an important component of Algerian fishery catch. Reproduction and growth parameter of this species are studied during 13 months, from fish catched from western Algerian coasts from December 2015 to December 2016. The sex-ratio (F:M) of the population studied is 1:1.56 and is in favor of male. The reproductive season extends between late spring and autumn. The resting period occurs in winter. Length at first maturity is estimated at 18.63 cm and 16.95 cm for females and males respectively. The length-weight relationship obtained is $TW=0.009TL^{3.086}$ ($R^2=0.983$). The Von Bertalanffy growth equation parameters are $K=0.41$, $L\infty=29.97$, $t_0=-0.34$ and the $\Phi'=2.57$.

KEY WORDS Algerian; growth; maturity; *Pagellus acarne*; reproduction; Western Mediterranean Sea.

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INTRODUCTION

Axillary seabream, *Pagellus acarne* (Risso, 1827) (Perciformes Sparidae), is a demersal Sparid fish, widely distributed in Mediterranean Sea and Black Sea. It is occurring in eastern Atlantic coasts from Senegal to Denmark and around the Madeira, Azores, Canary and Cape Verde Islands (Fischer et al., 1987). This species inhabits different type of sea bottom up to 500 m depth. However, it is more common between 40 to 100 m depth and is fished by trawling and artisanal fishing.

Pagellus acarne was studied for his biological feature in the Atlantic coast of Morocco and western Sahara, (Mennes, 1985; Lamrini, 1986), in the Canary Islands (Pajuelo & Lorenzo, 2000), in Portugal (Santos et al., 1995; Coelho et al., 2005) and in Atlantic coast of Spain (Velasco et al., 2011). The species was studied, also, in Mediterranean coasts (Andaloro, 1982), in Greece (Stergiou et al., 1997), in Turkish (Ozaydın et al., 2007; Soykan et al., 2015), in Mediterranean coasts of Spain (Dominguez, 2000; Valesco et al., 2011), in Mediterranean coasts of Morocco (Zoubi, 2001) and in Algerian water (Bensahla, 2014; Bouferaoui & Harchouche, 2015).

Sparid fish are one of the important components of fishery in Algeria. Species of this family have a great commercial value and are largely exploited. Moreover, *P. acarne* is listed by the International Union for Conservation of Nature (Russell et al., 2014). The aim of this paper is to give more information about parameters useful to assess biological feature of *P. acarne* (reproduction period, maturity, growth and age) from western Algerian waters.

MATERIAL AND METHODS

Sampling

Sampling was performed in western Algerian Sea (Fig. 1), off Bouzedjar port (35°34'57.83"N, 1°09'04.97"W) as this fishing port is one of the most important fishery of Algerian coasts

Pagellus acarne were sampled monthly between December 2015 and December 2016, from commercial trawling. All fish were measured for total length (TL, cm) to nearest 1 mm. Total weight (TW, g), eviscerate weight (EW, g), gonad weight (GW, g), to nearest 0.01g.

Sex and gonads maturation stages determination

Gonads were observed macroscopically. Sex was recorded for each fish sampled. Fish having only male gonads were determined to be male, fish having only female gonads were determinate to be female; and fish having both gonads (gonotestis) were determinate to be hermaphrodites and classified depending on the functional gonad in male or female for the estimation of parameters below (Valesco et al., 2011). Individuals with unidentifiable gonads were classified to be indeterminate (I). Four gonadal maturation stages were identified for male and female: (II) developing, (III) mature, (IV) spawning, (V) post spawning (Brown-Peterson et al., 2011).

The sex-ratio (F:M) was calculated and the chi-square test ($\chi 2$) was applied for determining the significance of the female to male ratio compared to the expected 1:1.

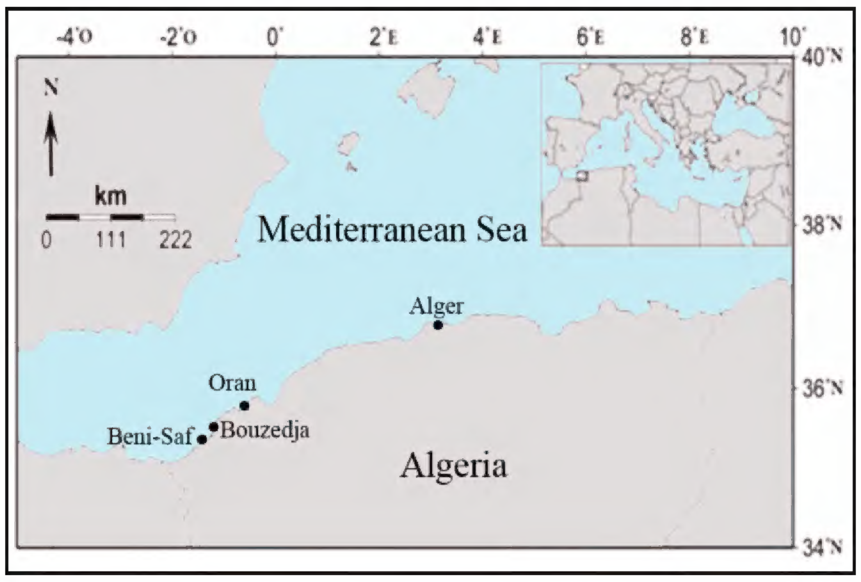

Figure 1. The study area: Bouzedjar port in western Algerian coasts.

Reproduction

The spawning period was determined by the monthly variation of the mean gonadosomatic index (GSI) (Pajuelo & Lorenzo, 2000; Velasco et al., 2011, Soykan et al., 2015), calculated as:

$$GSI=100*GW/EW.$$

Size at first maturity (L_{50}) was defined as the size at which 50% of invidious become mature (Batts, 1972), during the reproductive period. It is calculated according to ICES (2008) as:

$$P= 1/1+e^{(a+bTL)}$$

Where P is the proportion of mature individuals in size class of TL (cm), a and b are constants of non linear regression, and L_{50} is the size where 50% of the individuals are mature.

Growth

The length-weight relationship was estimated as:

$$WT = aLT^{b}$$

Where a and b are coefficients of the equation (Ricker, 1973). When the value is b=3, growth is isometric. Weight increase exhibits positive allometry if b>3 and negative allometry if b<3. The degree of association between variables Weight and length was calculated by the determination coefficient (R^2).

The Von Bertalanffy growth function was applied to size-at age data. The function is:

$$Lt = L\infty[1 - e^{-k(t-to)}]$$

In this equation, Lt is the mean fish length at age t (year), k ($year^{-1}$) is the growth coefficient; $L\infty$ (cm) is the asymptomatic length; and t_0 (year) is the hypothetic age at which length is equal to zero. All the parameters were calculated using ELEFAN method (electronic length-frequency analysis) integrating in LFDA program (Pitcher, 2002). Growth parameters were compared with other studies using the phi-prime test (Φ') (Munro & Pauly, 1983), where

$$\Phi' = \log(k) + 2\log(L\infty)$$

RESULTS

A total of 795 *P. acarne* were collected and examined. Morphometric characteristics are summarized in Table 1 and the frequency distribution of TL of all sample are illustrated in figure 2.

The sex-ratio (F:M) of the sample is 1:1.56. The proportion of female and male grouped among interval size of 1cm is significantly different ($\chi 2$ test, $P < 0.05$) for most size groups except for sizes ranged between 18 and 20 cm (Fig. 3). Significant differences are registered in monthly frequency distribution of males and females ($\chi 2$ test, $P < 0.001$) (Fig. 4).

Results on monthly frequency of the gonads maturation stages for males and females are demonstrated in figure 5. Monthly variations of mean GSI for both sexes are illustrated in figure 6. The higher values of GSI occur between May and July for females and one month earlier for male (between April and July) and between October and November for the two sexes, these coincide with presence of gonads at spawning stage. The first Peak of GSI occurs in June for female and in May for male and the second peak in October for the two sexes. Between the two peaks, a collapse of mean GSI is recorded in August. That coincides with presence of developing and post spawning gonads stages.

Size at first sexual maturity L_{50} is estimate at 18.63 cm for female and 16.95 cm for male.

Length-weight relationship parameters are consigned in Table 2. Isometric growth is observed for males and all sample, when slightly negative allometry is observed for females.

The Von Bertalanffy growth parameters are summarized in Table 3 and the curve of length at age is illustrated on figure 7.

DISCUSSION

The sex-ratio in this study is in favor of male. The same results were observed by Arculeo et al. (2000) and Valesco et al. (2011). In contrast and in all the other distribution area of *P. acarne* sex-ratio is in favor of females (Santos et al., 1995; Pajuelo & Lorenzo, 2000; Coelho et al., 2005; Bensahla, 2014; Soykan et al., 2015; Boufersaoui & Harchouche, 2015). The sex-ratio registers a seasonal variations, as it appears that in spawning season

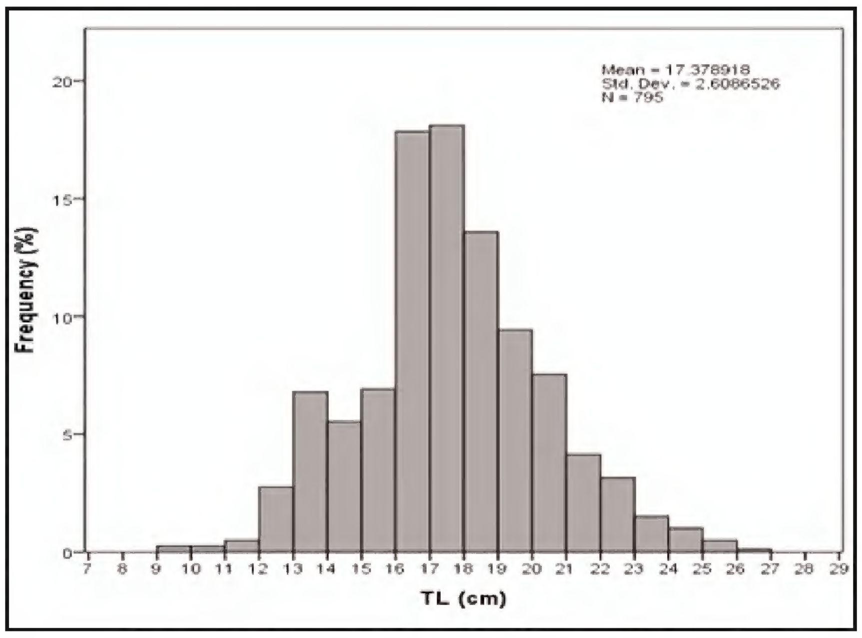

Figure 2. Length frequency diagram of *P. acarne* sampled from western Algerian coasts.

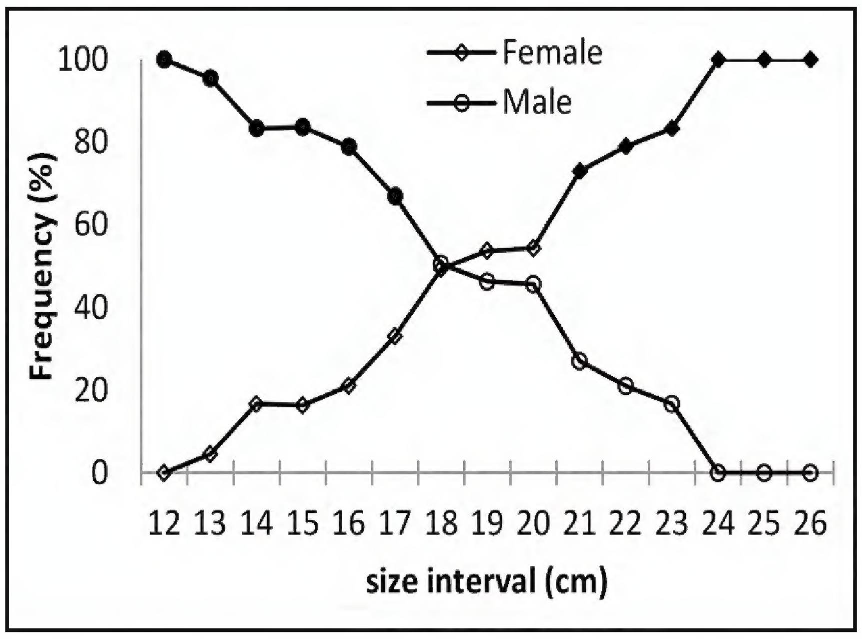

Figure 3. Frequency of females and male among intervals size (full marker: significant difference in frequency of males and females; dominant gender).

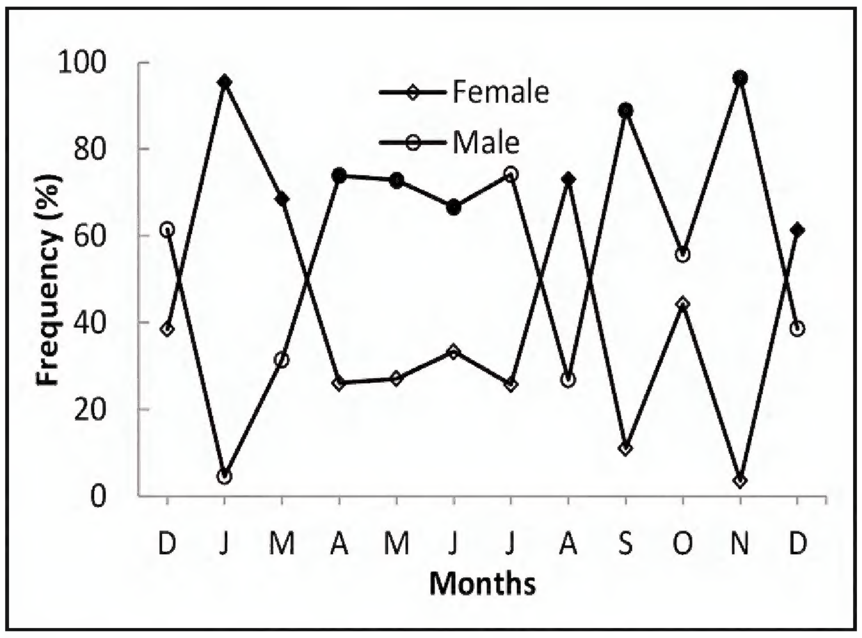

Figure 4. Monthly frequency of females and males of *P. acarne* (full marker: significant difference in frequency of males and females; dominant gender).

	TL		TW		N
	M±SD	Rang	M±SD	Rang	
Female	19.24±2.43	13.5-26.2	90.05±35.53	26.6-223	230
Male	16.81±1.81	12.9-22	58.21±19.99	22.98-148	280
Indeterminate	15.27±2.23	9.8-21	44.10±19.87	10.34-112	178
Hermaphrodite	18.39±2.11	13.8-24	77.74±27.71	28.29-169.32	107

Table 1. Morphometric characteristics of *P. acarne* sampled. M: mean; SD: standard deviation of the mean; N: number.

	a	b	R^2	N
female	0.0131	2.9716	0.9681	241
male	0.0095	3.0756	0.974	377
all	0.0092	3.0868	0.9835	795

Table 2. Parameters of length-weight relationship of *P. acarne* from western Algerian coasts.

	$L\infty$	k	t_0	Φ'	Equation de Von Bertalanffy
Female	29.79	0.5	-0.04	2.64	$Lt = 29.79(1 - e^{-0.5(t+0.04)})$
Male	28.43	0.42	-0.13	2.54	$Lt = 28.43(1 - e^{-0.42(t+0.13)})$
Combined	29.97	0.41	-0.34	2.57	$Lt = 29.97(1 - e^{0.41(t+0.34)})$

Table 3. Von Bertalanffy growth parameters of *P. acarne* from western Algerian coast.

Authors	Area	Male	Female
Andaloro (1982)	Tyrrhenian and Ionian Sea	16.5	
Lamrini (1986)	Atlantic	20.9	
Santos et al. (1995)	Atlantic	20.9	19.7
Pajuelo & Lorenzo (2000)	Atlantic	15.8	19.4
Coelho et al. (2005)	Atlantic	17.6	18.1
Valesco et al. (2011)	Atlantic	18.4	21.5
	Alboran Sea	17.7	20.1
Bensahla (2014)	W-Mediterranean	15.99	12.75
Boufersaoui et al. (2015)	W-Mediterranean	16.8	16.45
Soykan et al. (2015)	C-Aegean Sea	13.91	14.45
Present study	W-Mediterranean	16.95	18.63

Table 4. Size at first maturity (cm) from different distribution areas of *P. acarne*.

males are dominant and in resting season females are dominant. According to TL, males are dominant in smallest size and female in great size. This is a characteristic of protandric species; the fish are first male and became female.

Reproductive season of *P. acarne* shows two spawning periods. The first, between spring and early summer, with a peak of spawn in later spring and the second, in autumn, with a peak of spawn in October; between the two there is an interruption of spawning in August. The resting period occurs in winter. These results are in agreement with Bensahla (2014) and Boufersaoui & Harchouche (2015) along Algerian coasts. In higher latitudes spawning period occurs between end of spring and early autumn (Lamrini, 1986; Santos et al., 1995; Coelho et al., 2005; Valesco et al., 2011; Soykan et al., 2015). In contrast, in lower latitudes it is occurs between winter and spring (Pajuelo & Lorenzo, 2000). These geographical differences in reproductive season of *P. acarne* could be due to the environmental conditions influencing gonads maturation.

In this study, males attain sexual maturity at a smaller size than female. The same result is observed by Santos et al. (1995); Pajuelo & Lorenzo (2000); Valesco et al. (2011) and Soykan et al. (2015). It appears to be a characteristic of protandric hermaphrodite species. Table 4 summarizes size at first maturity of *P. acarne* registered by different authors. In the present study, first sexual maturity occurs at 16.95 cm for male and 18.63 cm for female (2 years for both sexes). This result agrees with size at first maturity reported in Mediterranean sea by Andaloro (1982) and Boufersaoui & Harchouche (2015) for males only. Even in Mediterranean Sea, smaller sizes at first maturity were obtained in Algerian coasts by Bensahla (2014) and in central Aegean Sea by Soykan et al. (2015). In contrast, Lamrini (1986) in Atlantic Ocean, Santos et al. (1995) in southern Portuguese coasts, Valesco et al. (2011) in Atlantic Ocean and Alboran Sea, report higher sizes at first maturity comparing to results obtained in this study. Water temperature is an important factor that influences metabolic activity; it is known that Mediterranean water is warmer than Atlantic water. That could explain that fish reach sexual maturity in Mediterranean at smaller size than fish in Atlantic. In addition, the effect of sampling biases cannot be excluded (Tsikliras & Stergiou, 2014).

Length-weight relationship shows an isometric growth for all individuals of *P. acarne*. Positive allometry is reported for axillary seabream in other distribution area in Mediterranean Sea (Valesco et al., 2011; Bensahla, 2014; Soykan et al., 2015) and in Atlantic (Santos et al., 1995; Pajuelo & Lorenzo, 2000; Coelho et al., 2005) (see Table 5). In this study there is a difference in the length-weight relationship between males and females which register slightly negative allometry. This observation is described by Pajuelo & Lorenzo (2000) and Valesco et al. (2011) for the same species. They explain it by the difference in the size distribution of the two sexes due to the protandric hermaphroditism.

The Von Bertalanffy growth parameters allow converting length of *P. acarne* to age. It appears that the younger fish sampled are under 1 year old and the oldest are between 4 and 4.5 years old. The most frequent age reported in the sample is approximately two years.

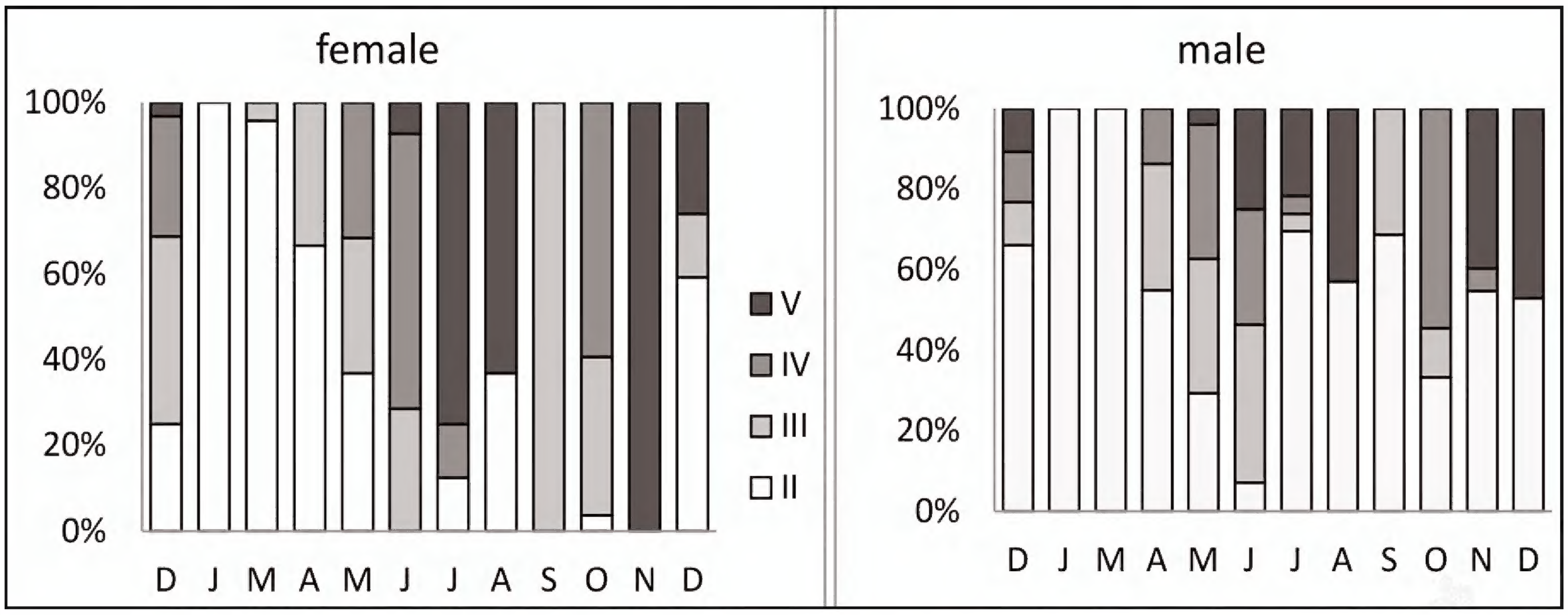

Figure 5. Monthly variation of the frequency of gonads development stages of *P. acarne*.

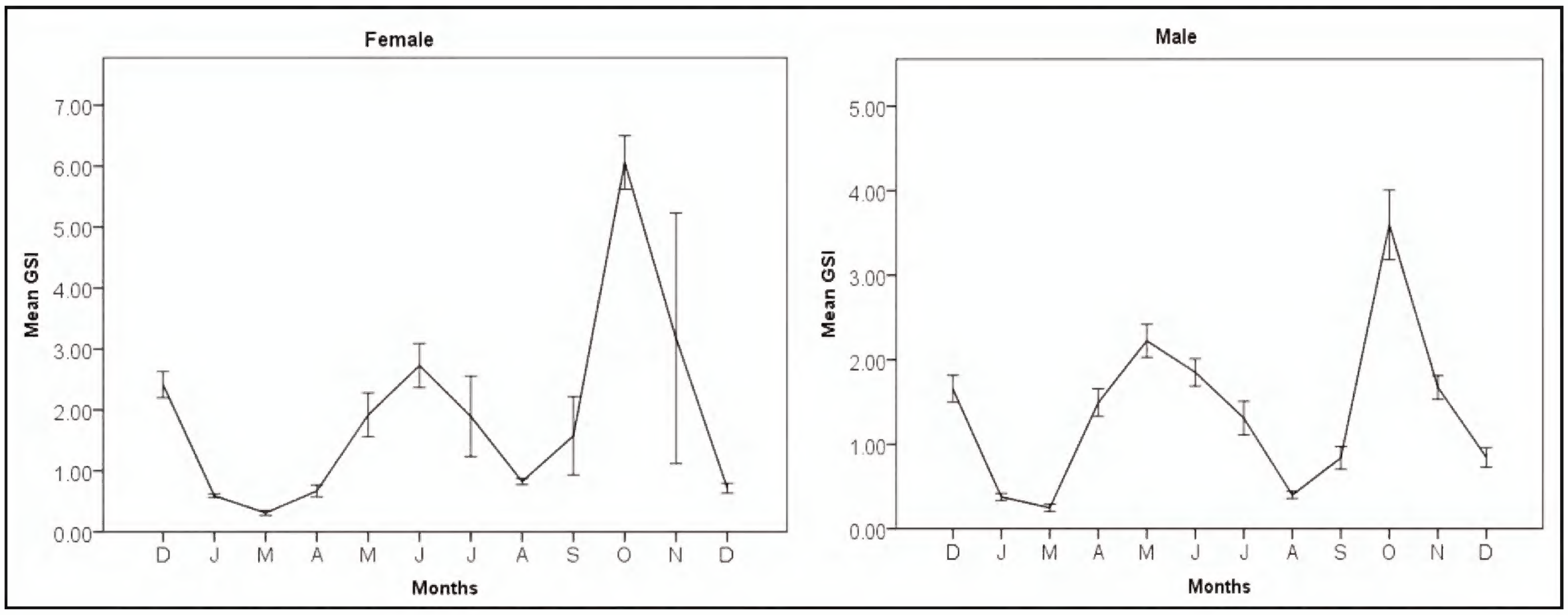

Figure 6. Monthly variation in the mean GSI with standard errors of *P. acarne*.

References	Sex	Rang (cm)	Growth				LWR		Area
			L_∞	K	t_0	Φ'	a	b	
Andeloro (1982)	F	8-28	29.78	0.32	-0.26				Italy, Tyrrhenian and Ionian Sea
	M		26.23	0.42	-0.22				
Mennes (1985)	C		31	0.21		2.3	0.02	3	Morocco, Atlantic
Djabali (1990)	C		24.4	0.3		2.46			Algeria, Mediterranean
Santos et al. (1995)	C						0.085	3.153	Portugal, Atlantic
Dominguez (2000)	C		29.62	0.27	-1.36				Spain, Alboran Sea
Pajuelo & Lorenzo (2000)	C	11-31	32.98	0.22	-0.87				Canary Islands
	F	16-31	33.9	0.21	-0.99	2.38	0.006	3.281	
	M	14-24	30	0.27	-0.67	2.39	0.007	3.242	
Zoubi (2001)	C		24	0.43	-0.21	2.39			Morocco, Mediterranean
Coelho et al. (2005)	C	12.4-36.5	32.05	0.18	-2.91		0.012	3.048	Portugal, Atlantic
	F	16.7-36.5	32.3	0.18	-2.56				
	M	15.9-30.0	28.2	0.29	-1.47				
Valesco et al. (2011)	C	11.3-30.9	31.7	0.21	-1.76	2.32	0.005	3.321	Spain, Golf of Cadiz
	C	10.7-29.4	32.1	0.17	-2.69	2.24	0.009	3.113	Spain, Alboran Sea
Bensahla (2014)	C		27.3	0.56	-0.155	4.621	0.008	3.1	Algeria, Western Mediterranean
	F	13-26.3	27.3	0.58	-1.49	4.636	0.11	3.053	
	M	13-23	27.3	0.56	-0.155	4.621	0.009	3.088	
Soykan et al. (2015)	C	8.5-20.2	22.6	0.31	-1.202	2.21	0.009	3.138	Turkey, Aegean Sea
	F	12.5-20.2					0.011	3.055	
	M	12.2-16.6					0.008	3.155	
Present study	C		29.97	0.41	-0.34	2.57	0.0092	3.0868	Algeria, Western Mediterranean Sea
	F	13.5-26.2	29.79	0.5	-0.04	2.64	0.0131	2.9716	
	M	12.9-24	28.43	0.42	-0.13	2.54	0.0095	3.0756	

Table 5. Von Bertalanffy growth parameters, length-weight relationship (LWR) of *P. acarne*, recorded from publications and present study.

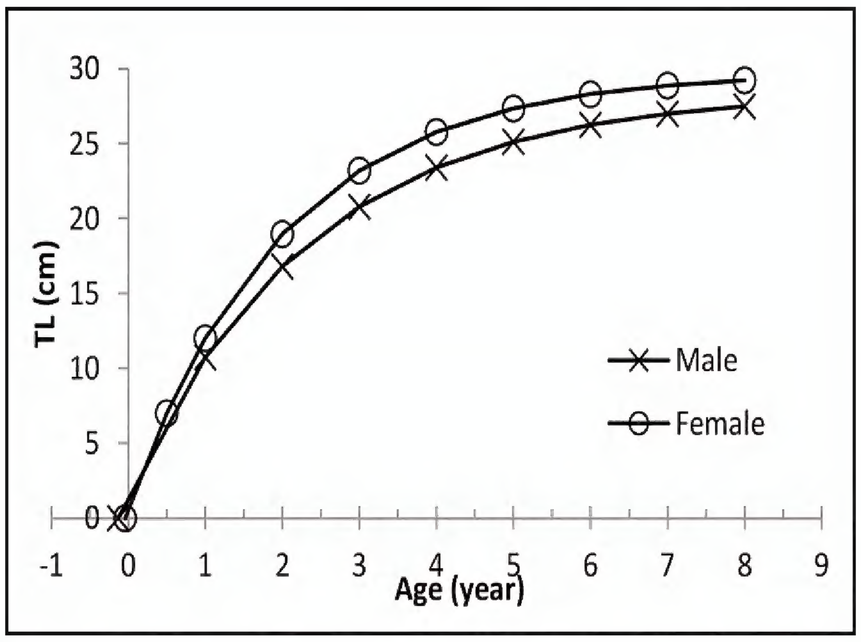

Figure 7. Length at age data from *Pagellus acarne* according to Von Bertalanffy growth equation.

Table 5 shows the growth parameters of *P. acarne* from different distributions areas. The k value in this study is estimated at 0.5 for female, 0.42 for male and 0.41 for the two sexes combinated. These K values indicate a rapid growth of the species in western Mediterranean water of Algeria. These values are close to the one obtained by Andeloro (1982) from Tyrrhenian and Ionian Seas, Zoubi (2001) in Mediterranean coast of Morocco, Bensahla (2014) in Bay of Oran in western Algerian coasts. However, they are higher than those reported by Djabali et al. (1990), Pajuelo & Lorenzo (2000), Coelho et al. (2005), Valesco et al. (2011), and Soykan et al. (2015). The asymptomatic length L∞ reported in this study is 29.79 for female, 28.43

for male and 29.97 cm for all samples. These values are reasonable regarding maximum TL registered from sampled fish. The L∞ values obtained are higher than those observed in Mediterranean Sea by Djabali et al. (1990), Zoubi (2001), Bensahla (2014), and Soykan et al. (2015). However, they are lower than those obtained in Atlantic Ocean by Pajuelo & Lorenzo (2000), Coelho et al. (2005), and Valesco et al. (2011). These differences in K and L∞ values could be attributable to size range of sampled fish and the fitted growth model. The phi prime values calculated in this study are slightly higher than the ones obtained by majority of works on *P. acarne* from his different distribution area (Table 5), but they are comparable to those obtained by Bensahla (2014) in the same geographic area.

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Orthetrum chrysostigma (Burmeister, 1839): new for the Italian fauna (Odonata Libellulidae)

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ABSTRACT Details about the first Italian record of *Orthetrum chrysostigma* (Burmeister, 1839) (Odonata Libellulidae), obtained in south-western Sicily, are reported. One mature male was collected in the province of Agrigento in August 2014.

KEY WORDS Dragonflies; first record; North Africa; Sicily; Italy.

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INTRODUCTION

Orthetrum chrysostigma (Burmeister, 1839) is one of the most widespread and common species of Libellulidae Anisoptera in Africa, its range expanding to southern Europe and Turkey with the northern limits of distribution in Portugal and the Ebro Delta in Spain, while the eastern limit is found in southern Anatolia (Boudot et al 2009; Boudot & Kalkman, 2015). In North Africa, it is very common in Tunisia, both in coastal areas with a high percentage of rainfall and in the oases of inner desert areas (Jödicke et al. 2000; Boudot et al., 2009; pers. obs.). The species is also well distributed in Morocco and Algeria (Jacquemin & Boudot, 1999; Boudot et al., 2009; Boudot & Kalkman, 2015; Corso pers. obs.). In Spain and Portugal the distribution range is rather wide with large populations (Boudot et al 2009; Boudot & Kalkman, 2015). For the island of Malta, four records are known between 2008 and 2010 (Gauci & Sciberras, 2010). It also appears that there may be a reproductive population on the island (Corso et al., 2012).

In Italy, there were no known records (Riservato et al., 2015).

MATERIAL AND METHODS

The area of Torre Salsa nature reserve (Agrigento, Sicily, Italy) was repeatedly visited, mainly during June to August, to observe and study Odonata. The site is of considerable interest for its environmental characteristics and the excellent state of conservation. Further, the relatively low distance from the African coasts (Tunisia), favours the discovery of rare or extra Italian species. All the sampling were carried out through identification from photographic documentation (see Aguesse, 1968; Askew, 2004; Dijkstra & Lewington, 2006; Gagliani et al., 2017). Only in few case, some specimens were caught by using entomological nets, observed for a more in-depth study, and then left free in the field again. The specimens here reported and discussed, however, were out of the nature reserve's borders, therefore it was decided to collect and preserve them (AC legit, M. Pavesi collection, Milano, Italy).

RESULTS

In August 2013, in the brackish ponds of the nature reserve of Torre Salsa, we thought we had observed *O. chrysostigma*. However, on 26th August 2014 other interesting *Orthetrum* sp. were observed just outside Torre Salsa Nature Reserve. Fortunately, 4 male were collected (37°22'31.48"N, 13°19'43.87"E). On closer examination, three of these specimens were determined as *O. coerulescens* (Fabricius, 1798), showing secondary genitalia intermediate between the typic *O. coerulerescens* and the taxon *O. coerulerescens anceps* (Schneider, 1845) (considered a separate species, a subspecies or simply a geographical variant of *O. coerulerescens*), or closer to the latter (Mauersberger, 1994, Klingenberg, 1994, Klingenberg & Martens, 1996) (Figs. 8, 9). Instead, 1 male was determined as a mature specimen of *O. chrysostigma*, based on its secondary genitalia morphology (Fig. 3) and the shape of the S3-S4 abdominal segments. This specimen, sent to M. Pavesi in order to confirm its identification (now kept in his entomological collection), represent the first ever record for Italy.

The structure of the secondary genitalia was found to be the key identification character: the anterior lamina appears to be very slightly protruding (Figs. 3, 4). The similar species are the aforementioned *O. coerulescens* (chiefly "*anceps*"), *Orthetrum nitidinerve* (Sélys-Longchamps, 1841), *O. brunneum* (Fonscolombe, 1837) and *O. ransonnetii* (Brauer, 1865) which results not yet recorded in Europe up to date. In both sexes, *O. chrysostigma* shows a characteristic pattern with pale bands diagonally across the thorax, called "epaulette" (Fig. 1). These pale bands differentiates it from other similar *Orthetrum* species observable in Europe and North Africa (Aguesse, 1968, Askew, 2004, Dijkstra & Lewington, 2006, Dijkstra & Clausnitzer, 2014). However, in mature, pruinose male, chiefly in old ones, this pattern is hardly appreciable or almost completely obscured, making it resembling the other species here above reported (Fig. 2). From *O. coerulescens* it is distinguished mainly by the anterior lamina of the secondary genitalia that appears decidedly less protruding, less prominent and more convex rather than concave (Figs. 3, 4, 7–9). Moreover, *O. coerulescens* (including the slender and more delicate looking "*anceps*") lacks the peculiar and unique tapering at the sides of the 3rd and 4th abdominal segments (S3–S4). Further, *O. chrysostigma* shows at the base of the wings (chiefly the hindwing) a small amber patch or spot, that could be more or less extensive, though sometimes hardly visible (or missing in forewing). *Orthetrum brunneum* appear rather different, being of a paler cerulean colour, appearing bigger, "heavier", with different genitalia (smaller anterior lamina and genital lobe) (Fig. 5). *Orthetrum nitidinerve* might appears similar, showing pale legs, a skinny, "light" body and a similar general colour. The analysis of the genitalia again makes easy the identification but, once detected the waisted abdominal segments (S3–S4), the determination it is easy also in the field. In addition, the unique pale yellow outer costa and inner vain of the forewing of nitidinerve is another helpful difference. In an extra European context, *O. ransonnetii* is the closest species showing very similar secondary genitalia (Fig. 6). *Orthetrum ransonnetii* shows a more "muscular", heavier general structure, longer and thicker upper appendages (Figs. 10, 11), has a darker membranula at the base of hindwings, which are lacking the pale amber patch or spot. As with all the other similar species, the tapering, waisted abdominal segments of *O. chrysostigma* readily distinguish it from *O. ransonnetii* as well.

DISCUSSION

Further on-site surveys carried out by us in August 2015–2019, have failed to detect additional imagoes of *O. chrysostigma*. Also, other researchers have carried out observations in the same years in July-August, without being able to detect the presence of the species (M. Pavesi, S. Surdo & C. Muscarella pers. com.). The area where we obtained this new odonata for Italy, it is of considerable relevance for the Sicilian fauna of dragonflies and damselflies, 21 species were recorded so far: *Calopteryx haemorrhoidalis* (Vander Linden, 1825), *Lestes barbarus* (Fabricius, 1798), *Ischnura geneii* (Vander Linden, 1820), *Ceriagrion tenellum* (Villers, 1789), *Erythromma lindenii* (Sélys, 1840), *Aeshna mixta* Latreille, 1805, *A. affinis* (Vander Linden, 1820), *A. isoceles* (Müller, 1767), *Anax imperator* Leach, 1815, *An. parthenope* Selys, 1839, *An. ephippiger* (Burmeister, 1839), *Orthetrum brunneum* (Fonscolombe, 1837), *O. coerulescens* (Fabricius, 1798), *O. cancellatum* (Linnaeus, 1758), *Crocothemis erythraea* (Brullé, 1832), *Sympetrum fonscolombii* (Sélys, 1840), *S. meridionale* (Sélys, 1841), *S. striolatum* (Charpentier, 1840), *Trithemis annulata*

(Palisot de Beauvais, 1805), *Selysiothemis nigra* (Vander Linden, 1825) and *Brachythemis impartita* (Karsch, 1890). Our record of *O. chrysostigma* brings the number of Odonata species recorded in Italy to 96 (Riservato et al., 2014; Viganò et al., 2017). This make Italy, together with France (96 species as well), the European country with the richest odonate fauna, followed by Spain (88) (Viganò et al., 2017). The total species number for Europe is 144 (cf. Boudot & Kalkman, 2015) and that for the Western Palaearctic is 201, with the latest addition of *Tramea basilaris* (Palisot de Beauvois, 1807) documented at Linosa (Pelagie islands, Sicily) (Viganò et al., 2017). At the current state of knowledge, it is not clear whether the record here reported is due to the presence of a small population settled in the study area (as happened on the island of Malta), or it is simply referable to occasional occurrence attributable to vagrants accidentally arrived from the Tunisian coasts (presumably in correspondence of strong scirocco or, even more, libeccio winds). In fact, the latter hypothesis is reflected by the observation of other migratory or dispersal species of odonata recently reported as new for the Italian fauna at the Pelagie islands and in Sicily: *Pantala flavescens* (Fabricius, 1798), *Trithemis kirbyi* Selys, 1891, *Sympetrum sinaiticum* Dumont, 1977 and *Tramea basilaris* (Palisot de Beauvois, 1807), the first two species being regularly recorded while the other being rare vagrants recorded only once or

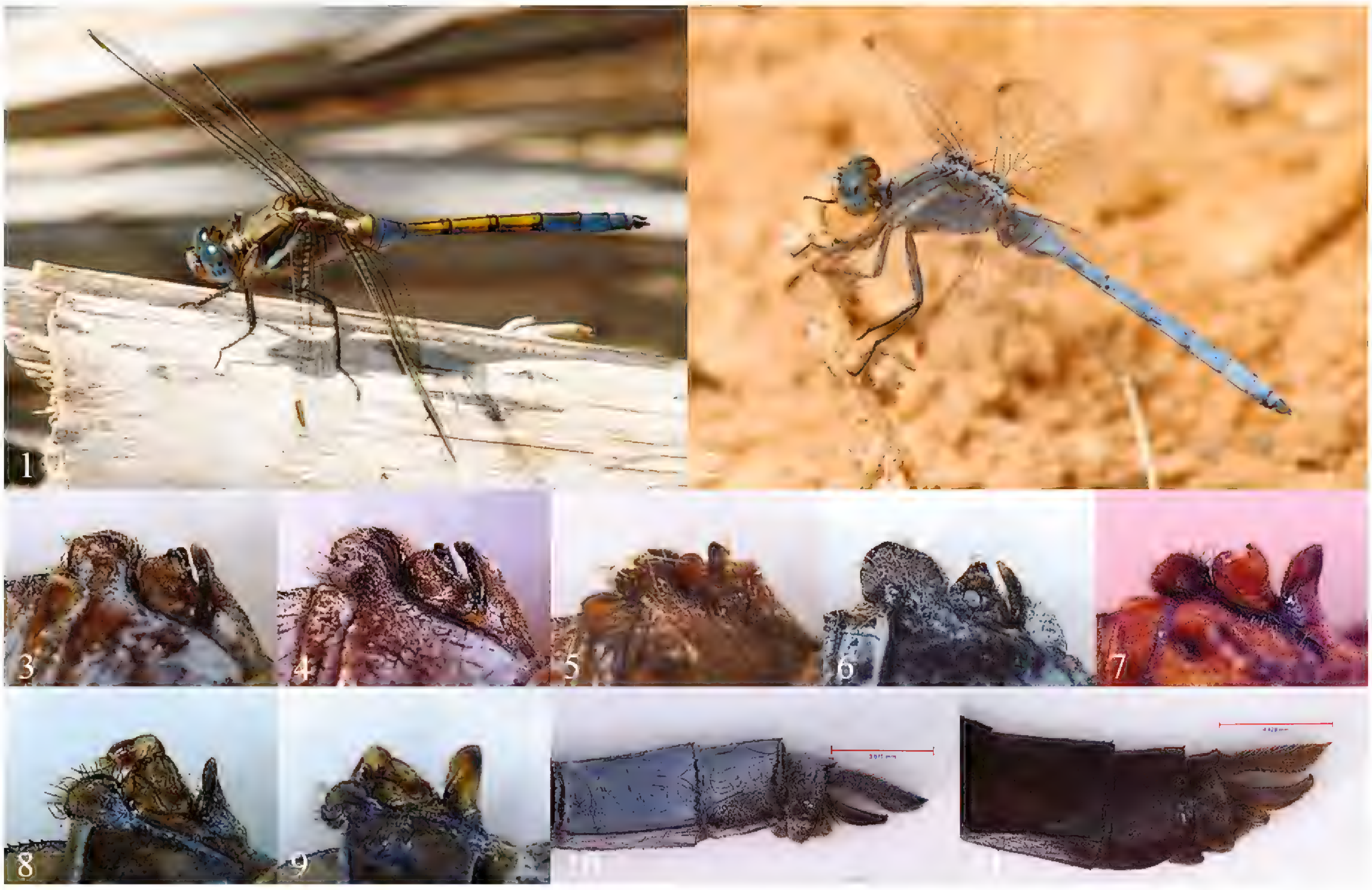

Figure 1. Young male of *Orthetrum chrysostigma*, 13.IV.2019, Morocco, Aoulouz, AC. Note the characteristic pale band ("epaulette") typical of this species. Figure 2. Mature male of *O. chrysostigma*, Morocco, Aoulouz, 13.IV.2019, AC. Note that old pruinose males may lack altogether the typical "epaulette" or barely show this pattern, making the identification harder. In older male the pale band is not visible at all. Compared to other European Orthetrum sp. note the slender abdomen, which is waisted at segments S3-S4, the pale membranula and the amber coloured small patch at the base of hindwing. Figure 3, 4. Secondary genitalia of the mature male of *O. chrysostigma.* Fig. 3: Torre Salsa (Agrigento, Sicily, Italy), 37°22'31.48"N, 13°19'43.87"E, 26.VIII.2014 (AC). Fig. 4: Morocco, near Aoulouz, 13.IV.2019. Figure 5. Idem, *O. brunneum*, Italy, Sicily, Castelvetrano, 30.VII.2011, AC. Figure 6. Idem, *O. ranssonnetii*, Morocco, Askaoun, Anti-Atlas, 2.III.2011, AC. Figure 7. Idem, *O.* cf. *coerulescens* ssp., Italy, Sicily, Fiume Anapo (Siracusa), 25.VII.2013, AC. Figure 8. Idem, *O.* cf. *coerulescens* (closer to "*anceps*"), Italia, Torre Salsa (Agrigento, Sicily), 26.VIII.2014, AC. Figure 9. Idem, *O. coerulescens* (intermediate?), Italy, Torre Salsa (Agrigento, Sicily), 26.VIII.2014, AC. Figure 10. Appendages of the mature male of *O. chrysostigma*, Torre Salsa (Agrigento, Sicily, Italy), 26.VIII.2014. Figure 11. Idem, *O. ranssonnetii*, Morocco, Askaoun, Anti-Atlas, 2.III.2011.

twice (Corso et al., 2012, 2017; Viganò et al., 2017). It is doubtless and was indeed demonstrated by our researches, that thanks to strong south winds, and in particular weather condition, vagant species may easily reach Sicily and its surrounding islands: these may colonise in the future the area, or may simply, most probably, remains rarities. Other species should be actively searched in Sicily and its circum-Sicilian islands, such as *Orthetrum sabina* (Drury, 1770), and *Ischnura saharensis* Aguesse, 1958 to quote some of them, while *Diplacodes lefebvrii* (Rambur, 1842) was recently recorded from the island of Linosa, Pelagie Archipelago (Agrigento, Sicilian Channel) (Janni et al., 2020).

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On the presence of the African catfish *Clarias anguillaris* (Linnaeus, 1758) (Siluriformes Clariidae) in south-eastern Algeria (Ifni-Illizi)

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ABSTRACT Experimental fisheries carried out in August 2019 made it possible to report the presence of a species of freshwater fish, Mudfish *Clarias anguillaris* (Linnaeus, 1758) (Siluriformes Clariidae), to Guelta Ifni (Illizi) an integral part of the Tassili N'Ajjer National Park (south-eastern Algeria). This species is on the IUCN red list as Least Concern (LC) being a taxon that does not qualify for Critically Endangered, Endangered, Vulnerable or Nearly Threatened. Surveys of 16 morphometric variables and three meristics, representing specific distinguishing characteristics, established on two male specimens, confirm this determination. This new locality will complete the current inventory of freshwater species reported in southern Algeria as well as the mapping of the distribution of the species in the in the African continent.

KEY WORDS Algeria; *Clarias anguillaris*; Ifni; Illizi; Morphometric; Meristic.

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INTRODUCTION

In South of Algeria despite the existence of several water bodies, the studies on the ichthyo-fauna are rare. The objective of this study is the identification and reporting for the first time in this locality of a species of African catfish, Mudfish *Clarias anguillaris* (Linnaeus, 1758) (Siluriformes Clariidae). The greatest diversity of the Clariidae family is found in Africa with 14 genera and 92 species and in Asia with two genera and some 17 species currently known (Teugels, 1996). The genus *Clarias* Scopoli, 1777 is the most widespread of the Clariidae family and it is represented by 32 species on the African continent (Teugels, 1986, 1992; Teugels et al., 2007).

African catfish *Clarias anguillaris* (Linnaeus, 1758) was found in a Guelta of the Ifni zone, where recent studies were not carried to update the inventory of the aquatic fauna of the extreme south of Algeria, particularly the Tassili N'Ajjer massif, which represents a protected area. This species which has a status LC (Least Concern) for its protection, according to the IUCN (Azeroual et al., 2010).

"Asataf" is the local name of the African catfish in southern Algeria, and these fishes are highly valued by consumers accounting an important source of animal protein for rural populations, especially in these Algerian regions (Bartley et al., 2015). The residents of the Ihrir Valley, in particular the Tuaregs of the region, have had a very important relationship with these fish for centuries. The presence of the species at the Ifni site encourages the measures of its protection and promises the development of a sustainable Saharan aquaculture.

MATERIAL AND METHODS

Study area

The African catfish, Mudfish *Clarias anguillaris*, was found in the Guelta of the Saharan rural area named Ifni, a village of Tassili N'Ajjer located 150 km from the capital of the willaya of Illizi, Algeria (25°45'51.4'N and 007°54'53.8' E) (Figs. 1, 2).

Samples

Two specimens of *Clarias anguillaris* were caught in August 2019 via fishing with a rod of 6 m, and a wire of 5 m, with hook of a total length of 30 mm and an opening of 10 mm. The bait consisted of a cooked paste (fish feed flour with a protein content of 40 %) mixed with wheat flour.

Specimens were transported to the laboratory for biometric measurements. The weights of the

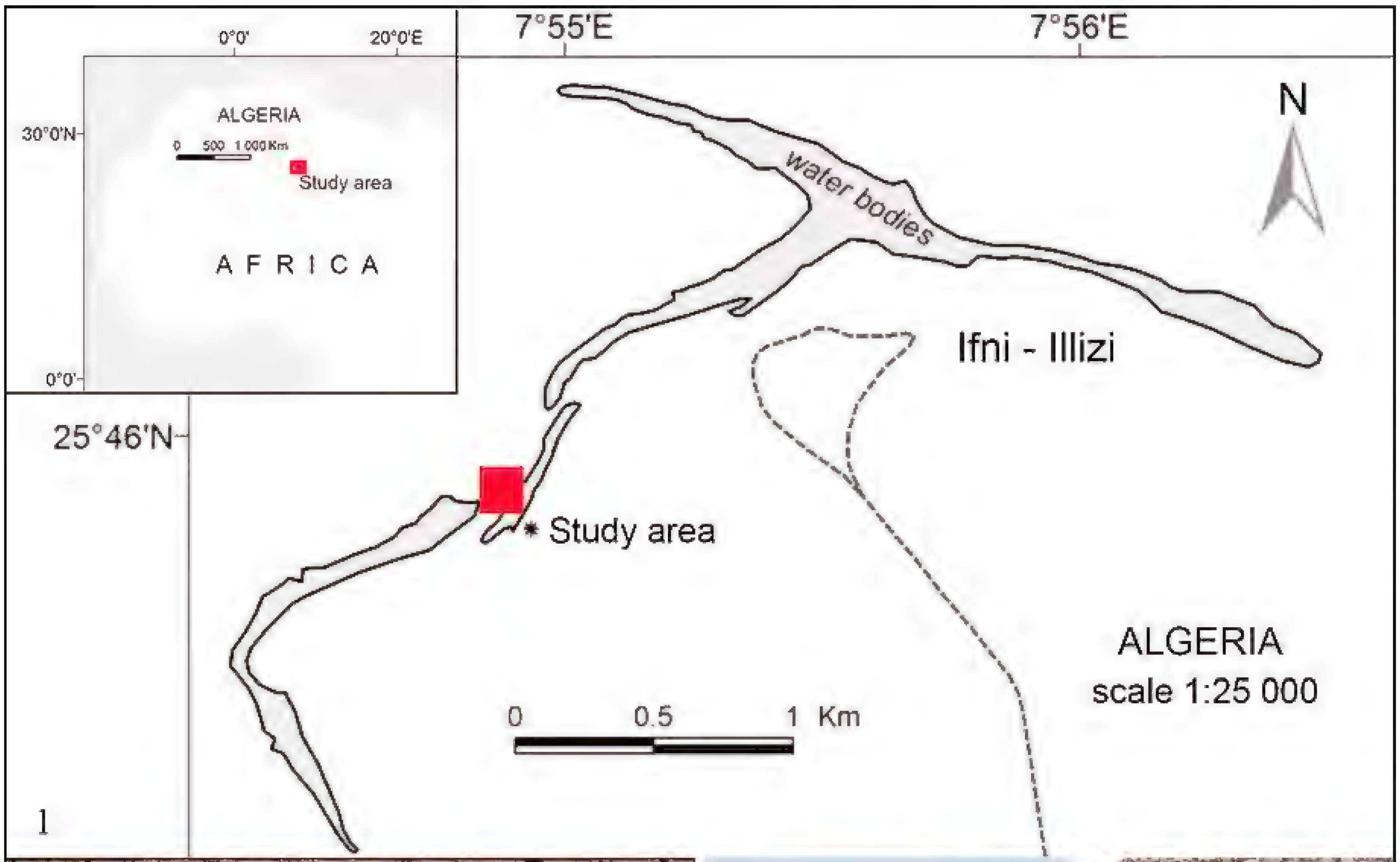

0°0'
20°0'E
30°0'N
ALGERIA
0 500 1 000 Km
Study area
AFRICA
0°0'
7°55'E
7°56'E
N
water bodies
Ifni - Illizi
25°46'N
Study area
ALGERIA
scale 1:25 000
0 0.5 1 Km
1

Figure 1. Map of geographical location of study area of Ifni - Illizi (south-eastern Algeria). Figure 2. Guelta Ifni sangling area.

specimens obtained by means of an electronic field precision scale with a maximum of 500 x 0.01 g, and the morphometric measurements made by means of sliding feet (0.05 mm) and a metric band.

Methodology

On each sample, 16 morphometric variables and three meristic variables were carried out for the identification of this siluriform according to Lévêque et al. (1990). The meristic counts carried out are: the number of branchiospines on the first branchial arch, number of dorsal fin rays, and number of anal fin rays (Teugels et al., 1998; Swain & Foote 1999; Turan, 2004) (Fig. 3). The percentages of morphometric measurements are given in relation to the standard length (SL) for the body and the Head length (HL). These data are shown in Table 1. The analyses and data collection were performed using Excel 2010 software.

ABBREVIATIONS. 1. Total length (TL); 2. Standard length (SL); 3. Body depth (BD); 4. Head length (HL); 5. Snout length (SNL); 6. Eye diameter (Ed); 7. Predorsal length (PDL); 8. Preanal Length (PAL); 9. Prepectoral Length (PPCL); 10. Pre-pelvic length (PPVL); 11. Length of dorsal-fin base (LDF); 12. Length of anal-fin base (LNA); 13. Pectoral-fin length (PECF); 14. Pelvic fin length (PELF); 15. Caudal-peduncle length (CPL); 16. Depth of caudal-peduncle (DCP). Number of dorsal fin rays (RD); number of anal rays (RA); number of branchiospines on the first branchial arc (BR).

RESULTS AND DISCUSSION

Systematics

Superclassis OSTEICHTHYES Huxley, 1880
Classis ACTINOPTERYGII Klein, 1885
Ordo SILURIFORMES G. Cuvier, 1817
Familia CLARIIDAE Bonaparte, 1846
Genus *Clarias* Scopoli, 1777

Clarias anguillaris (Linnaeus, 1758)

DESCRIPTION. The main morphometric variables measured on both specimens are shown in Table 1 for the first (a) and the second (b) specimen. The size of the first fish is 256 mm (LT), 236.5 mm of standard length (LS), 73 mm of head length and weight of 128.2 g. The size of the second specimen is 260 mm, 231 mm of standard length (LS) 70 mm cranial length and weight of 147.84 g. The head is very long with an average of 31% of the standard length (LS) (Figs. 4, 5).

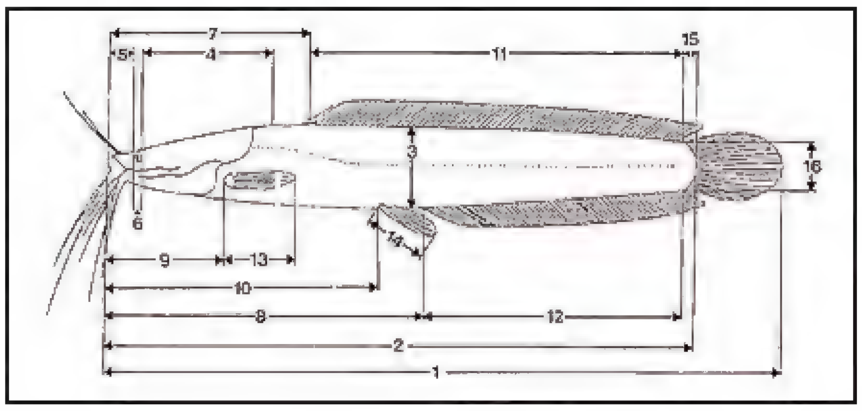
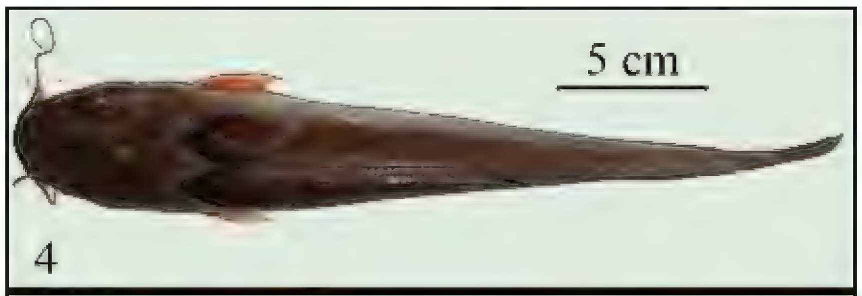
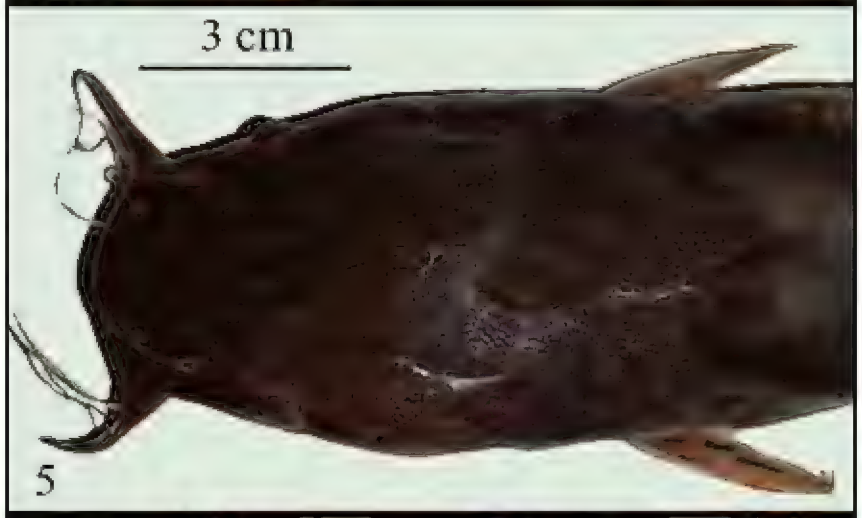


Figure 3. Diagram showing the measurements made (Lévêque et al. 1990).





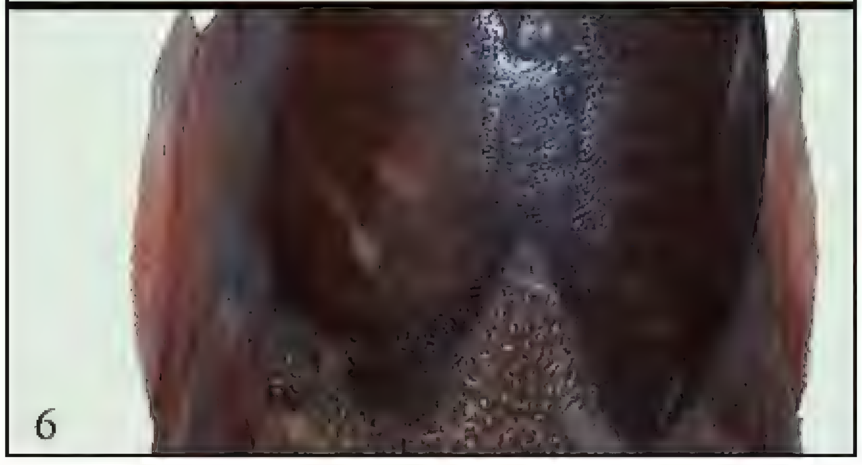


Figure 4. Front view of the body of *Clarias anguillaris* fished at Guelta of Ifni. Figure 5. Idem, dorsal view of the head. Figure 16. Idem, denticulate pectoral spine on anterior part.

The results of the parameters studied above coincide well with the range of proportions proposed by Teugels (1982a, b) for the two specimens in our study.

The results of the three meristic variables are presented in Table 2.

The number of rays at the dorsal fin (RD) is 72 in the first *C. anguillaris* (a) and 59 in the second (b). The number of anal fin rays (AR) is 51 in the first *C. anguillaris* (a) and 48 in the second (b).

The first specimen of *C. anguillaris* has 25 branchiospines and the second has 32 branchiospines. The pectoral spine is identified on the anterior part (Fig. 6); the neuromasts on the flanks show a regular pattern for the specimen reported to Ifni.

DISTRIBUTION. *Clarias anguillaris* is known from the lower Nigeria Cross River, Mauritania, southern Algeria and the Nile (Teugels, 1986; Paugy et al., 2003; Teugels et al., 2007). It is present also in Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Egypt, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, South Sudan, Togo (Azeroual et al., 2010).

Code	The abbreviations	Catfish Male (a)	Catfish Male (b)	Teugels,1982 in mm
0	W (g)	128.2	147.84	/
1	TL (mm)	256	260	/
2	SL (mm)	236.5	231	(119.7-426)
3	BD (SL %)	12.68	14.29	(9.2-16.3)
4	HL(SL %)	30.87	30.30	(29.1-33.6)
5	SNL (SL %)	20.55	22.86	(19.6-22.9)
6	Ed (HL %)	9.59	7.14	(5.9-10.2)
7	PDL (SL %)	35.94	37.66	(32.9-38.4)
8	PAL (SL %)	54.97	58.44	(53.2-59)
9	PPCL (SL %)	25.37	26.41	(22.5-28.9)
10	PPVL (SL %)	45.67	48.48	(44.3-49.9)
11	LDF (SL %)	59.35	58.87	(54.4-64.7)
12	LNA (SL %)	41.19	43.29	(39.4-44.6)
13	PECF (SL %)	11.84	12.55	(11.4-14.6)
14	PELF (SL %)	10.99	11.26	(7.3-11.4)
15	CPL (SL %)	2.33	3.90	(3-5.7)
16	DCP (SL %)	5.50	6.93	(5.7-9.4)

Table 1. Body measurements for *Clarias anguillaris from* Guelta of Ifni compared with reference Teugels, 1982a, b.

HABITAT AND ECOLOGY. *Clarias anguillaris* is a demersal, potamodromous species, that is widespread in flooded areas. It lives mainly in deep waters, in muddy and semi-muddy bottoms, and bury itself in mud when water bodies dry up. According to Albaret (1982), the reproduction of some *Clarias* is generally limited to the flood period. The diets of the different *Clarias* are very similar in their food. According to Lauzanne (1988), they consume insects and larvae of insects, various crustaceans, molluscs, fish, plant debris, and combined with their ability to breathe atmospheric oxygen, these fish can adapt to the harshest living conditions, hence their presence in the Saharan areas.

REMARKS. *Clarias anguillaris* is very similar to *C. gariepinus* Burchell, 1822. The only net difference between the two species is the number of branchiospines on the first branchial arch, which is much smaller (15-60) in *C. anguillaris* (Fig. 10).

Clariidae are distinguished from other Siluriformes by the combination of lack of spine to the dorsal, very long dorsal and anal fins, an anguilliform type body, the presence of four pairs of barbels and a supra-organbranchial, formed by evaginations of the second and fourth branchial arc, allowing fish to practice aerial breathing. This organ is synapomorphic for the family (Teugels & Adriaens, 2003). Several species, including those of the genera *Clarias* and *Heterobranchus* É. Geoffroy Saint-Hilaire, 1809, play an important role in fishing and fish farming (Paugy et al., 2003).

The genus *Clarias* is characterized by the presence of a single dorsal fin extending up to the caudal (Fig. 7), the adipose being absent. Vertical fins are not confluent. The body is more or less elongated, with the caudal peduncle measuring less than 50% of the standard length.

The head is flattened and longer (20-34% LS), the lateral cephalic bones are generally contiguous. The eyes, with free-edge, are very small (Fig. 8), The genus *Clarias* was divided into six sub-genera (Teugels 1982b, 1986; Teugels & Adriaens, 2003; Agnese & Teugels, 2001; Jansen et al., 2006 demonstrated that the genus is paraphyletic.

The Head Length represents 27-35% of LS; 16-110 branchiospines throughout the first branchial arch; the postorbital bones are fully contiguous; the lower part of the head shows two blackish lateral bands; neuromasts on the sides form a regular pattern, which is consistent with the observations reported for the species.

CONCLUSIONS

Our results, compared with those of Compaoré et al. (2015) in Burkina Faso, reveal the presence of *C. anguillaris* in the southern Algeria.

	RD	RA	BR
***Clarias anguillaris* (a)**	72	51	25
***Clarias anguillaris* (b)**	59	48	32
Teugels, 1982	60-82	42-61	16-50

Table 2. Distinguishing characteristics of the two specimens of the genus *Clarias anguillaris* from Guelta of Ifni compared to Teugels (1982a).

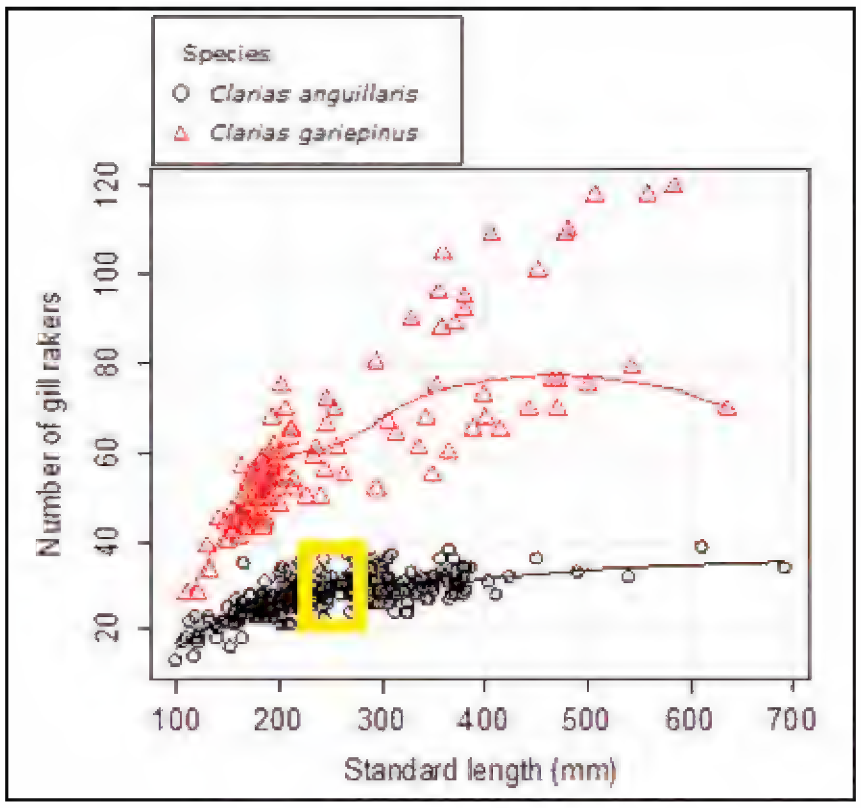


Figure 14. Number of branchiospines on the first branchial arch relative to standard length (LS) in *Clarias gariepinus* and *C. anguillaris* (Compaoré et al., 2015).

The presence of *C. anguillaris* in Guelta Ifni, wilaya Illizi, an integral part of the Tassili N'Ajjer National Park, testifies to a past as wet location and the presence of an interesting aquatic fauna. This study helps to improve knowledge on the inventory of the aquatic species of the southern Algeria and on distribution of the species in the African continent. The presence of *C. anguillaris* in this large and protected territory is reassuring for the future monitoring of this species

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Check-list of the vascular flora of the "Bosco di Gibilmanna", a Special Area of Conservation (S.A.C.) in northern Sicily (Italy)

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ABSTRACT This paper reports the results of a floristic survey carried out in the area falling within the S.A.C. ITA020002 "Boschi di Gibilmanna e Cefalù" (Sicily, Italy), a site with a marked environmental heterogeneity lying from almost sea level to over 1000 meters of altitude. On the basis of our investigations, a total of 605 taxa has been detected, including some endemic or rare species, as *Anthemis cupaniana* Tod. ex Nyman, *Arabis collina* Ten. subsp. *rosea* (DC.) Minuto, *Brassica incana* Ten., *Hieracium racemosum* Waldst. & Kit. ex Willd. subsp. *crinitum* (Sm.) Rouy, *Melittis melissophyllum* L. subsp. *albida* (Guss.) P.W. Ball., *Stachys sylvatica* L., *Symphytum gussonei* F.W. Schultz, *Viburnum tinus* L., etc. A map with floristic emergencies has been prepared in order to highlight the sites with the greatest conservation interest in the area. Besides, the taxonomical, biological and chorological composition of this flora is analyzed and discussed.

KEY WORDS Mediterranean; Plant conservation; Endemism; Madonie.

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INTRODUCTION

The Madonie massif, located in north-western Sicily, represents one of the main hotspots of plant biodiversity in the Mediterranean area, hosting about 1500 taxa and 170 endemisms (Raimondo et al., 2004a). The central highest part of the massif is quite well studied from a floristic and vegetational point of view (see Raimondo, 1980, 1984a, 1984b; Brullo, 1984), while specific contributions on the lower northern slopes are very scarce. Although this area does not present a phytogeographical interest comparable to that of the mountain belt, it is characterized by the presence of valuable plant communities and rare species, within a strongly anthropized and degraded context. In particular, the Gibilmanna wood, located in the hills above Cefalù, retains some interesting forest communities, as well as sporadic aspects of chasmophilous vegetation on the limestone outcrops and temporary ponds. The first investigations about the flora of this area date back to first half of the nineteenth century, due to Enrico Pirajno di Mandralisca (1809–1864), a nobleman with wide cultural and naturalistic interests (Domina & Mazzola, 2005), who owned a large estate in Gibilmanna. Between the end of the nineteenth and the beginning of the twentieth century other botanists provided new data, including Michele Lojacono Pojero (1853–1919), author of a monumental Flora Sicula, and Domenico Lanza (1868–1940), who usually spent the summer time in his house of Contrada Pianetti inside the Gibilmanna wood. Later, only sporadic floristic reports about this area have been quoted by Raimondo & Mazzola (1983), Raimondo et al., (1994, 2004b) and Falci & Giardina (2004). Therefore, the compilation of a floristic list for the S.A.C. ITA020002 "Boschi di Gibilmanna e Cefalù" represents the first attempt to provide a more complete and punctual account of the plant heritage occurring in the lower belt of Madonie massif.

MATERIAL AND METHODS

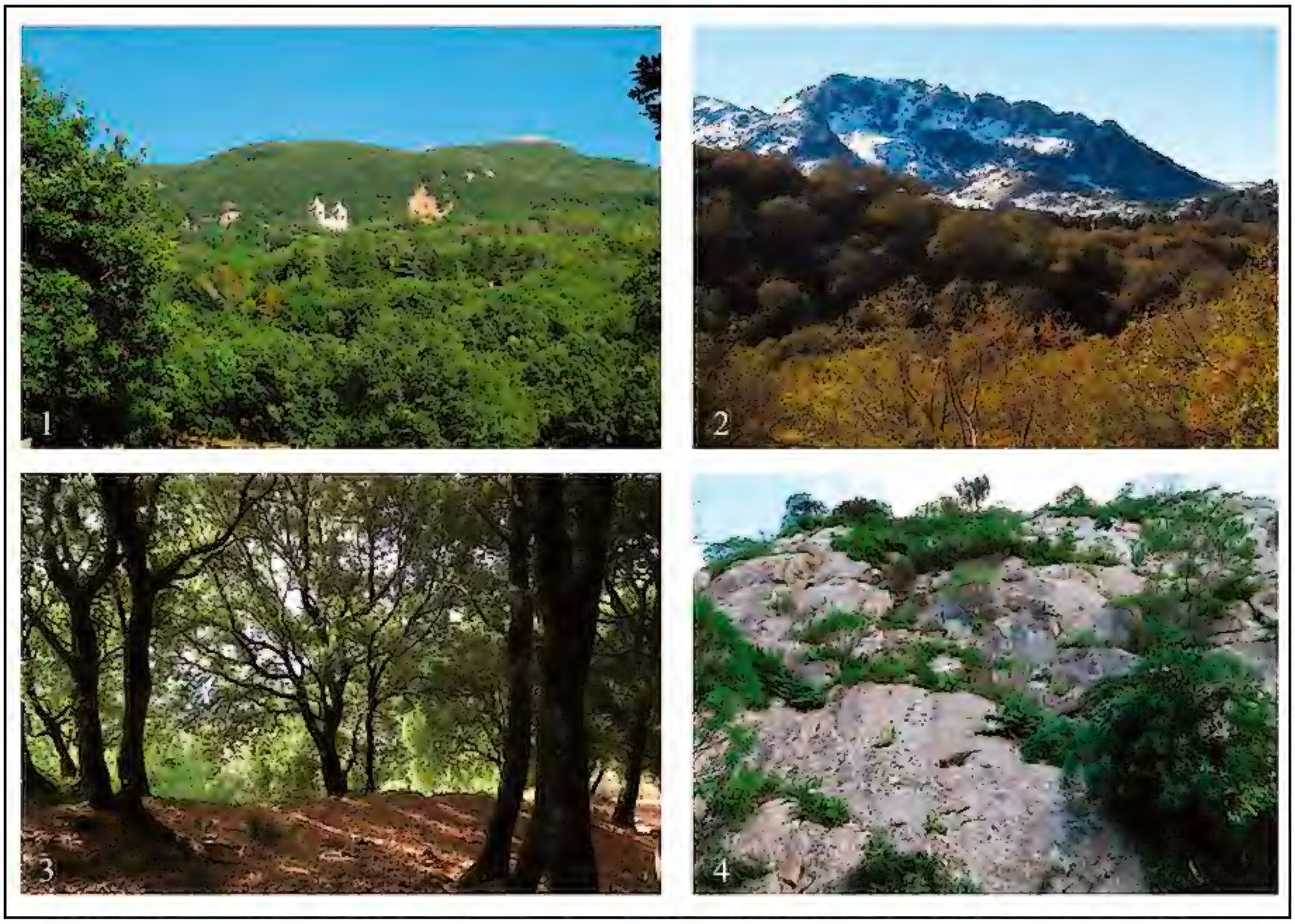
The boundaries of the investigated area coincide with those of the S.A.C. ITA020002 "Boschi di Gibilmanna e Cefalù" (Sicily, Italy), covering a surface of 2570 ha. It includes a quite heterogenous territory from the low hills above Cefalù at 150–200 m of altitude until the top of Pizzo Sant'Angelo at 1081 m. From the geological point of view, it is mainly constituted by substrata belonging to Numidian Flysch formation, mixed with scattered limestone outcrops. The flyschoid areas are characterized by gentle and rounded morphologies, while the calcareous ones show sharp ridges, deep valleys and macro- or micro-karst microforms. Until the second post-war period this area was probably intensely cultivated at least up to 600–700 m above sea level, while subsequently it became a popular holiday resort both for its proximity to Cefalù and for the particularly favorable climatic conditions in summer (Palmeri, 2007). Actually, the lower stands shows a spreading urbanization, sometimes interrupted by small patches of scrub with *Spartium junceum* and *Bupleurum fruticosum* belonging to *Spartio juncei-Bupleuretum fruticosi* Raimondo & Ilardi 2009 and few relicts of *Pinus pinea* forests (*Cisto cretici-Pinetum pineae* Brullo, Minissale, Siracusa, Scelsi, Spampinato 1993), often replaced by low garrigues with *Cistus creticus* and *Cistus salvifolius*. The quite evolved soils with loose texture are instead colonized by communities dominated by *Quercus suber*, which represent impoverished and thermophilous aspects of the *Genisto aristato-Quercetum suberis* Brullo 1983. The cork oak woods are widespread from 150 to 650 m, although occupy fairly small areas and often appear in a very degraded condition. Above 500 m, they are gradually replaced by deciduous oak woods dominated by *Quercus virgiliana*, often characterized by a dense undergrowth with *Erica arborea* and *Arbutus unedo*. This community, referable to *Erico arboreae-Quercetum virgilianae* Brullo & Marcenò 1985, still covers large surfaces in correspondence with flat or slightly inclined surfaces with deep and humid soils (Figs. 1, 2). It lacks only in the slopes with a marked inclination and shallow soils, where it is replaced by a dense woody community with *Quercus ilex*, generally spread from 600 m to the top of Pizzo Sant'Angelo (Fig. 3). Sometimes, the woody vegetation is replaced by less evolved stages belonging to the same dynamic series, as perennial grasslands and shrublands. Among the other relevant plant communities, the greater example of chasmophilous vegetation occurs in the calcareous rocks of Rocca San Nicola (Fig. 4), while an interesting temporary pond is located near the road between Gibilmanna and Gratteri. Finally, some places (e.g., contrada Romito and Colombo) are characterized by artificial woods with *Castanea sativa*, now abandoned and severely damaged by fungal diseases, and small reforestations with *Pinus* sp. pl. or less frequently also *Eucalyptus* sp. pl.

The field surveys for this floristic research have been carried out during the years 2012–2019 in different seasons. The nomenclature follows Bartolucci et al. (2018) and Galasso et al. (2018). Besides, Flora of Italy (Pignatti, 1982; 2017–2019), Med-Checklist (Greuter et al., 1984; 1986) and Flora Europaea (Tutin et al., 1964–1980) were also consulted. The collected samples are preserved in the herbarium of the Department of Biological, Geological and Environmental Sciences of Catania University (CAT).

This study regards the native and naturalized vascular flora, highlighting the species of particular phytogeographic interest, whose location has been indicated with GIS mapping.

RESULTS AND DISCUSSION

Our investigations have allowed to record 605 species and intraspecific taxa of vascular plants, native or naturalized. The pteridophytic component is represented by 11 taxa, while only one conifer has been detected. The angiosperms are clearly more numerous, being represented by 593 taxa. Among the dicotyledons, the richest families are Asteraceae (79 taxa), Fabaceae (61), Caryophyllaceae (28), Lamiaceae (26), Apiaceae (24) and Brassicaceae (17). The monocotyledons are represented mainly by Poaceae (44), Orchidaceae (35) and Liliaceae (17). The biological spectrum (Fig. 5) reveals the



Figures 1–4. S.A.C. ITA020002 "Boschi di Gibilmanna e Cefalù" (Sicily, Italy). Figs. 1, 2: View of the woods around the Gibilmanna sanctuary. Fig. 3: Holm oak wood near Pizzo Sant'Angelo. Fig. 4: Limestone cliffs near Rocca San Nicola.

prevalence of terophytes (38%), followed by hemicryptophytes (29%), geophytes (18%), phanerophytes (7%), chamaephytes (4%), nanophanerophytes (3%) and hydrophytes (1%).

As regards the chorotypes (Fig. 6), the Stenomediterranean is the most frequent (30%), while the Eurimediterranean represents the 19%. Among others, the Cosmopolitan (6%), Eurasian (5%), Paleotemperate (5%), South Mediterranean (3%), Mediterranean-Turanian (3%), West Mediterranean (3%), Sub-cosmopolitan (2%), Eastern Mediterranean (2%), European-Caucasian (2%) and Circumboreal (2%) can be mentioned. A special mention must be given to the alien species, which represent only the 4% of the total flora, including 12 terophytes, 6 geophytes, 4 phanerophytes and 1 hemicryptophyte. The endemic elements are represented by 32 taxa (5%), including all species restricted to Sicily, Italy or a few neighboring areas. In particular, the Sicilian endemisms are *Anthemis cupaniana*, *Bellevalia dubia* subsp. *dubia*, *Dianthus siculus*, *Echium italicum* subsp. *siculum*, *Odontites vernus* subsp. *siculus*, *O. archimedea*, *Ophrys lunulata*, *Pimpinella gussonei*, *Symphytum gussonei* (Fig. 9) and *Trifolium bivonae*.

In addition, to the endemic species, the flora of the investigated area is characterized by some rare taxa or with a phytogeographical interest, such as *Astragalus echinatus*, *Isoëtes durieui*, *Lavandula stoechas* subsp. *stoechas*, *Melittis melissophyllum* L. *albida*, *Serapias nurrica* subsp. *nurrica*, *Silene fruticosa*, *Viburnum tinus* subsp. *tinus* (Fig. 7), whose local distribution is shown in figure 11. As regards the latter, during the present study a small population almost certainly indigenous was found in Contrada Romito along a small stream inside the holm oak wood. A particularly interesting group from a phytogeographic point of view is represented by the species that in this area reach the western limit of their range in Sicily, such as *Brassica incana*, *Bupleurum fruticosum*, *Hieracium racemosum* subsp. *crinitum* (Fig. 10) and *Stachys sylvatica*

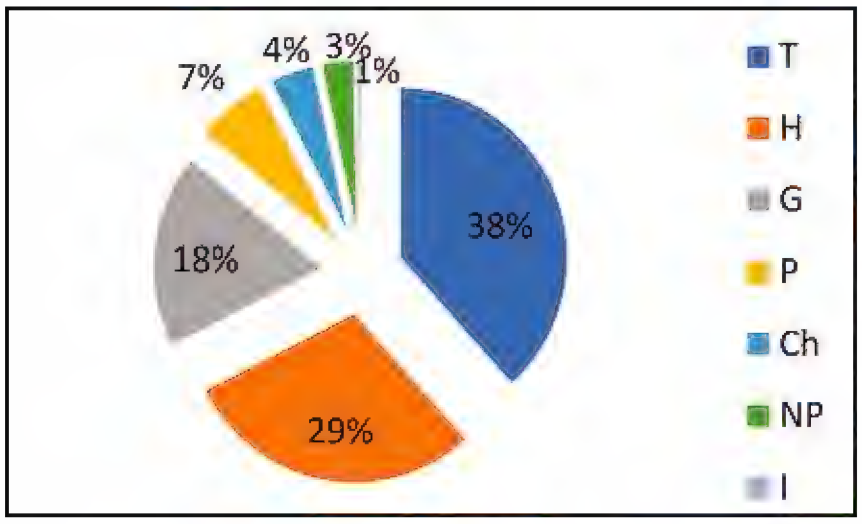


Figure 5. Biological spectrum of the vascular flora.

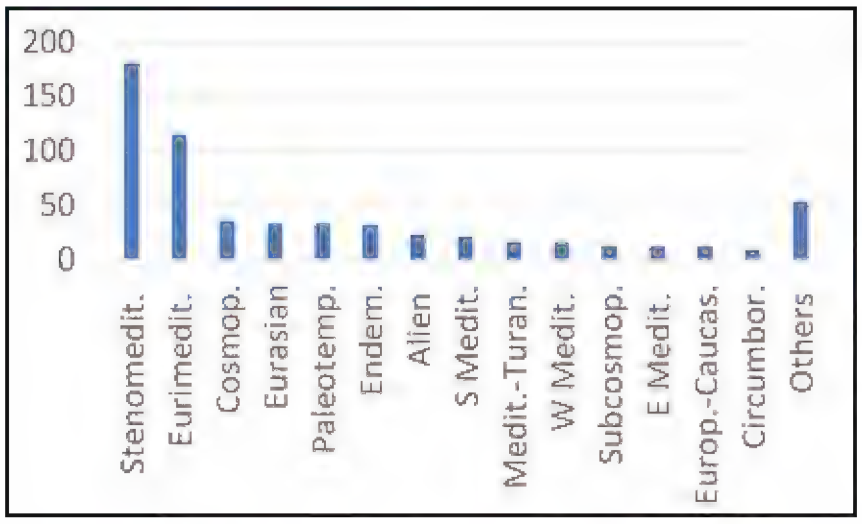


Figure 6. Chorological spectrum of the vascular flora.

(Fig. 8). In fact, the Gibilmanna wood shows some intermediate features between the Madonita and Nebrodense districts from an ecological, vegetational and floristic point of view. Its woody vegetation is clearly related to that of the nearby Nebrodi mountains, also due to the common presence of flyschoid substrates and the similar climatic conditions, as well as the isolated limestone outcrops host a chasmophilous flora closer to that of the Madonie massif and in general of north-western Sicily.

FLORISTIC LIST

PTERIDOPHYTA
EQUISETACEAE
Equisetum telmateia Ehrh.

SELAGINELLACEAE
Selaginella denticulata (L.) Spring,

ISOETACEAE
Isoëtes durieui Bory

ADIANTACEAE
Adiantum capillus-veneris L.

DENNSTAEDTIACEAE
Pteridium aquilinum (L.) Kuhn subsp. *aquilinum*

POLYPODIACEAE
Polypodium cambricum L.

ASPLENIACEAE
Asplenium onopteris L.
Asplenium trichomanes L. subsp. *trichomanes*
Asplenium ceterach L. subsp. *ceterach*

DRYOPTERIDACEAE
Dryopteris pallida (Bory) Maire & Petitm. subsp. *pallida*
Polystichum setiferum (Forssk.) T. Moore ex Woyn.

SPERMATOPHYTA
GYMNOSPERMAE
PINACEAE
Pinus pinea L.

ANGIOSPERMAE
ACANTHACEAE
Acanthus mollis L. subsp. *mollis*

AMARANTHACEAE
Achyranthes sicula (L.) All.
**Amaranthus albus* L.
**Amaranthus blitum* L. subsp. *blitum*
**Amaranthus cruentus* L.
**Amaranthus deflexus* L.
**Amaranthus graecizans* L. subsp. *silvestris* (Vill.) Brenan
**Amaranthus hypocondriacus* L.
**Amaranthus retroflexus* L.
**Amaranthus viridis* L.

AMARYLLIDACEAE
Allium polyanthum Schult. & Schult.f.
Allium roseum L. subsp. *roseum*
Allium sphaerocephalon L. subsp. *arvense* (Guss.) Arcang.
Allium subhirsutum L. subsp. *subhirsutum*
Allium triquetrum L.
**Amaryllis bella-donna* L.
Narcissus miniatus Donn.-Morg., Koop. & Zonn

Narcissus obsoletus (Haw.) Spach
Narcissus papyraceus Ken Gawl.
Narcissus tazetta L. subsp. *tazetta*

ANACARDIACEAE
Pistacia lentiscus L.
Pistacia terebinthus L. subsp. *terebinthus*
**Rhus coriaria* L.

APIACEAE
Ammoides pusilla (Brot.) Breistr.
Anthriscus nemorosa (M.Bieb.) Spreng.
Athamanta sicula L.
Bupleurum fruticosum L.
Bupleurum tenuissimum L.
Chaerophyllum temulum L.
Conium maculatum L.
Daucus carota L. s.l.
Eryngium campestre L.
Eryngium tricuspidatum L. subsp. *bocconei* (Lam.) Wörz
Eryngium triquetrum Vahl
Foeniculum vulgare Mill subsp. *piperitum* (Ucria) Bég.
Foeniculum vulgare Mill. subsp. *vulgare*
Kundmannia sicula (L.) DC.
Oenanthe globulosa L.
Oenanthe pimpinelloides L.
Pimpinella anisoides V. Brig.
Pimpinella gussonii Bertol.
Scandix pecten-veneris L. subsp. *pecten-veneris*
Smyrnium olusatrum L.
Smyrnium perfoliatum L. subsp. *perfoliatum*
Thapsia garganica L. subsp. *garcanica*
Tordylium apulum L.
Torilis arvensis (Huds.) Link subsp. *arvensis*
Torilis nodosa (L.) Gaertn. subsp. *nodosa*

APOCYNACEAE
Vinca major L. subsp. *major*

ARACEAE
Arisarum vulgare O.Targ.Tozz. subsp. *vulgare*
Arum italicum Mill. subsp. *italicum*
Biarum tenuifolium (L.) Schott subsp. *tenuifolium*

ARALIACEAE
Hedera helix L. subsp. *helix*

ASPARAGACEAE
Asparagus acutifolius L.
Bellevalia dubia (Guss.) Kunth subsp. *dubia*
Charybdis pancration (Steinh.) Speta
Loncomelos narbonensis (L.) Raf.
Muscari comosum (L.) Mill.
Muscari commutatum Guss.
**Oncostema elongatum* (Parl.) Speta
Ornithogalum montanum Cirillo ex Ten.
Prospero autumnale (L.) Speta
Ruscus aculeatus L.

ASPHODELACEAE
Asphodeline lutea (L.) Rchb.
Asphodelus fistulosus L.
Asphodelus ramosus L. subsp. *ramosus*

ASTERACEAE
Achillea ligustica All.
Anthemis arvensis L. subsp. *arvensis*
Anthemis cupaniana Tod. ex Nyman
Arctium minus (Hill) Bernh.
Artemisia arborescens (Vaill.) L.
Bellis annua L. subsp. *annua*
Bellis perennis L.
Bellis sylvestris Cirillo
Calendula arvensis (Vaill.) L.
Carduus argyroa Biv.
Carduus pycnocephalus L. subsp. *pycnocephalus*
Carlina gummifera (L.) Less.
Carlina involucrata Poir.
Carlina lanata L.
Carlina sicula Ten. subsp. *sicula*
Carthamus lanatus L.
Centaurea calcitrapa L.
Centaurea sicula L.
Centaurea solstitialis L. subsp. *schouwii* (DC.) Gugler
Cichorium intybus L.
Cirsium creticum (Lam.) d'Urv. subsp. *triumfetti* (Lacaita) K. Werner
Cirsium scabrum (Poir.) Bonnet & Barratte
Cirsium vulgare (Savi) Ten. subsp. *vulgare*
Coleostephus myconis (L.) Cass. ex Rchb.f.
Crepis vesicaria subsp. *hyemalis* (Biv.) Babc.
Crupina crupinastrum (Moris) Vis.
Cynara cardunculus L. subsp. *cardunculus*
Dittrichia graveolens (L.) Greuter
Dittrichia viscosa (L.) Greuter subsp. *viscosa*
Doronicum orientale Hoffm.
Echinops siculus Strobl
Eclipta prostrata (L.) L.
**Erigeron bonariensis* L.
Eupatorium cannabinum L.

Filago eriocephala Guss.
Filago germanica (L.) Huds.
Filago pygmaea L.
Filago pyramidata L.
Galactites tomentosus Moench
**Galinsoga parviflora* Cav.
Glebionis coronaria (L.) Spach
Glebionis segetum (L.) Fourr.
Hedypnois rhagadioloides (L.) F.W. Schmidt
Helminthotheca aculeata (Vahl) Lack subsp. *aculeata*
Helminthotheca echioides (L.) Holub
Hieracium racemosum Waldst. & Kit. ex Willd. subsp. *crinitum* (Sm.) Rouy
Hyoseris radiata L.
Hypochaeris achyrophorus L.
Hypochaeris radicata L.
Lactuca sativa L. subsp. *serriola* (L.) Galasso, Banfi, Bartolucci & Ardenghi
Lactuca viminea (L.) J. Presl & C. Presl subsp. *viminea*
Lapsana communis L. subsp. *communis*
Leontodon tuberosus L.
Logfia gallica (L.) Cosson & Germ.
Mycelis muralis (L.) Dumort. subsp. *muralis*
Notobasis syriaca (L.) Cass.
Onopordum illyricum L.
Pallenis spinosa (L.) Cass. subsp. *spinosa*
Pentanema squarrosum (L.) D. Gut. Larr., Santos-Vicente, Anderb., E. Rico & M.M. Mart.Ort.
Picris hieracioides L.
Pulicaria dysenterica (L.) Bernh.
Pulicaria odora (L.) Rchb.
Reichardia picroides (L.) Roth
Scolymus grandiflorus Desf.
Scolymus maculatus L.
Scorzonera hirsuta (Gouan) L.
Senecio leucanthemifolius Poir. subsp. *leucanthemifolius*
Senecio lividus L.
Senecio vulgaris L. subsp. *vulgaris*
Silybum marianum (L.) Gaertn.
Sonchus asper (L.) Hill subsp. *asper*
Sonchus oleraceus L
**Symphyotrichum squamatum* (Spreng.) G.L. Nesom
Taraxacum minimum (V.Brig.) N. Terracc
Taraxacum officinale (L.) Weber ex F.H. Wigg.
Tragopogon porrifolius L.
Urospermum dalechampii (L.) F.W. Schmidt
Urospermum picroides (L.) Scop. ex F.W. Schmidt
Xanthium italicum Moretti
**Xanthium spinosum* L.

BORAGINACEAE
Aegonychon purpurocaeruleum (L.) Holub
Anchusa azurea Mill.
Borago officinalis L
Cerinthe major L. subsp. *major*
Cynoglossum creticum Mill.
Echium italicum L. subsp. *siculum* (Lacaita) Greuter & Burdet
Echium plantagineum L.
Heliotropium europaeum L.
Myosotis ramosissima Rochel subsp. *ramosissima*
Myosotis sylvatica Hoffm. subsp. *elongata* (Strobl) Grau
Symphytum gussonei F.W. Schultz

BRASSICACEAE
Arabidopsis thaliana (L.) Heynh.
Arabis collina Ten. subsp. *collina*
Arabis collina Ten. subsp. *rosea* (DC.) Minuto
Arabis hirsuta (L.) Scop.
Arabis verna (L.) R. Br.
Biscutella maritima Ten.
Brassica incana Ten.
Brassica rapa L. subsp. *campestris* (L.) A.R. Clapham
Capsella bursa-pastoris (L.) Medik. subsp. *bursa-pastoris*
Cardamine hirsuta L.
Diplotaxis erucoides (L.) DC. subsp. *erucoides*
Draba verna L. subsp. *praecox* (Steven) Rouy & Foucaud
Draba verna L. subsp. *verna*
Isatis canescens DC.
Lobularia maritima (L.) Desv.
Lunaria annua L.
Raphanus raphanistrum L. subsp. *raphanistrum*
Sinapis pubescens L. subsp. *pubescens*

CACTACEAE
Opuntia ficus-indica (L.) Mill.

CAMPANULACEAE
Campanula dichotoma L.
Campanula erinus L.
Jasione montana L.

CANNABACEAE
Celtis australis L. subsp. *australis*

CAPPARACEAE
Capparis spinosa L.

CAPRIFOLIACEAE
Lonicera implexa Aiton subsp. *implexa*

CARYOPHYLLACEAE
Arenaria leptoclados (Rchb.) Guss. subsp. *leptoclados*
Arenaria serpyllifolia L. subsp. *serpyllifolia*
Cerastium brachypetalum Desp. ex Pers. subsp. *brachypetalum*
Cerastium glomeratum Thuill.
Cerastium semidecandrum L.
Dianthus siculus C. Presl
Eudianthe coeli-rosa (L.) Endl.
Petrorhagia dubia (Raf.) G. López & Romo
Petrorhagia illyrica (L.) P.W. Ball & Heywood subsp. *haynaldiana* (F.N.Williams) P.W.Ball & Heywood
Petrorhagia prolifera (L.) P.W. Ball & Heywood
Petrorhagia saxifraga (L.) Link subsp. *gasparrinii* (Guss.) Greuter & Burdet
Petrorhagia saxifraga (L.) Link subsp. *saxifraga*
Polycarpon tetraphyllum (L.) L. subsp. *diphyllum* (Cav.) O. Bolós & Font Quer
Polycarpon tetraphyllum (L.) L. subsp. *tetraphyllum*
Sabulina tenuifolia (L.) Rchb. subsp. *tenuifolia*
Sagina apetala Ard. subsp. *apetala*
Silene colorata Poir.
Silene conica L.
Silene fruticosa L.
Silene fuscata Brot.
Silene gallica L.
Silene italica (L.) Pers. subsp. *sicula* (Ucria) Jeanm.
Silene latifolia Poir.
Silene nocturna L. subsp. *nocturna*
Silene vulgaris (Moench) Garcke subsp. *tenoreana* (Colla) Soldano & F. Conti
Silene vulgaris (Moench) Garcke subsp. *vulgaris*
Stellaria neglecta Weihe subsp. *cupaniana* (Jord. & Fourr.) Gutermann
Stellaria neglecta Weihe subsp. *neglecta*
Stellaria pallida (Dumort.) Crép.

CHENOPODIACEAE
Chenopodium album L. subsp. *album*

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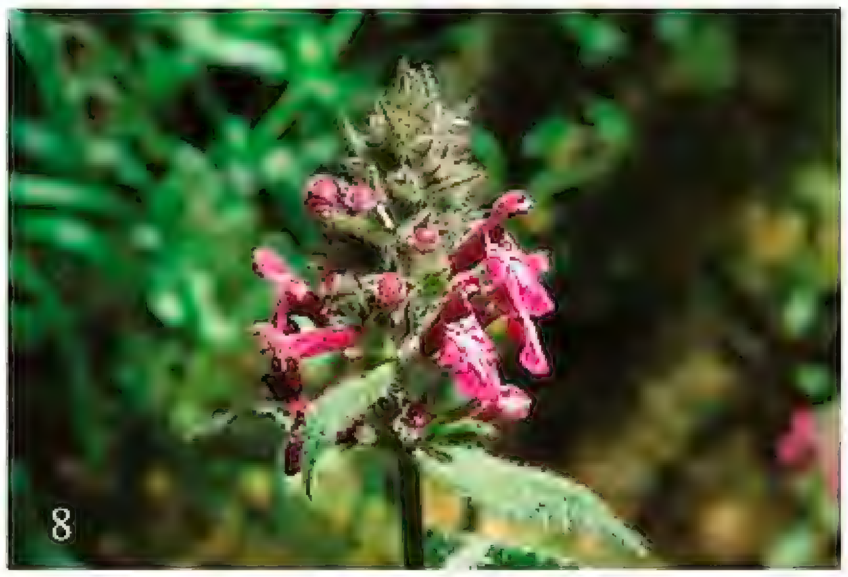
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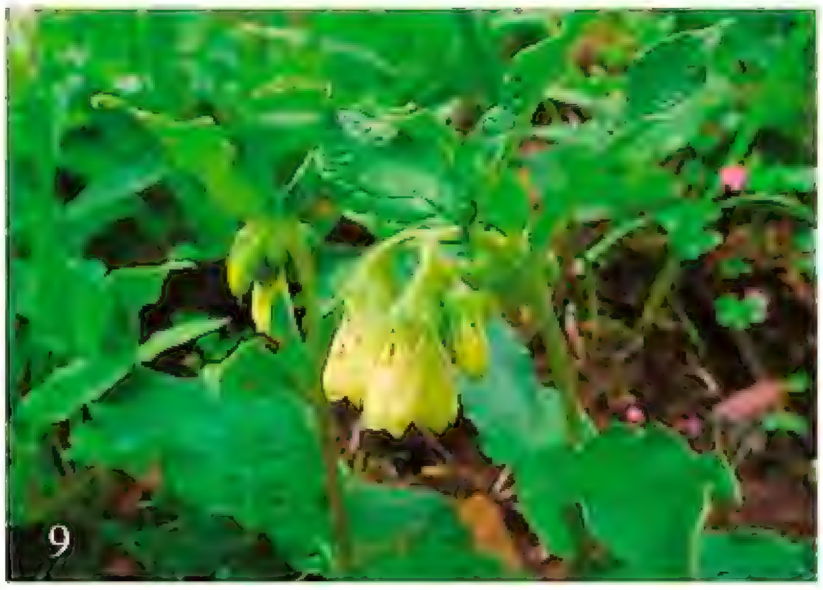
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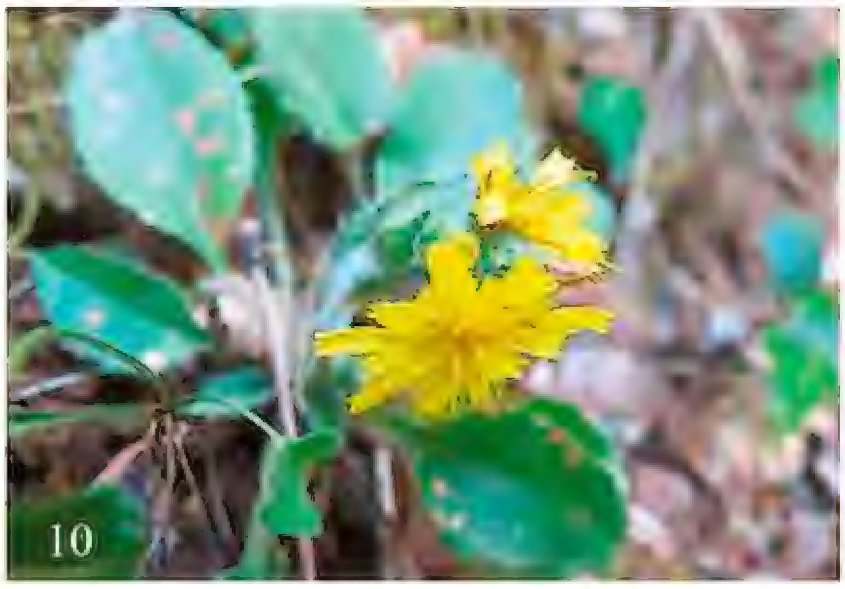
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Figure 7. *Viburnum tinus* subsp. *tinus*. Figure 8. *Stachys sylvatica*.
Figure 9. *Symphytum gussonei*. Figure 10. *Hieracium racemosum* subsp. *crinitum*.

Chenopodiastrum murale (L.) S. Fuentes, Uotila & Borsch
Chenopodium vulvaria L.

CISTACEAE
Cistus creticus L. subsp. *eriocephalus* (Viv.) Greuter & Burdet
Cistus monspeliensis L.
Cistus salvifolius L.
Tuberaria guttata (L.) Fourr.

COLCHICACEAE
Colchicum bivonae Guss.

CONVOLVULACEAE
Convolvulus sepium L.
Convolvulus althaeoides L.
Convolvulus arvensis L.
Convolvulus cantabrica L.
Cuscuta epithymum (L.) L. subsp. *epithymum*
Ipomoea indica (Burm.) Merr.

CRASSULACEAE
**Aeonium arboreum* (L.) Webb & Berth.
Petrosedum amplexicaule (DC.) Velayos
Petrosedum sediforme (Jacq.) Grulich
Phedimus stellatus (L.) Raf.
Sedum album L. subsp. *album*
Sedum caeruleum L.
Sedum cepaea L.
Sedum dasyphyllum L
Umbilicus horizontalis (Guss.) DC.
Umbilicus rupestris (Salisb.) Dandy

CUCURBITACEAE
Bryonia dioica Jacq.

CYPERACEAE
Carex caryophyllea Latourr.
Carex distachya Desf.
Carex flacca Schreb. subsp. *erythrostachys* (Hoppe) Holub
Carex hallerana Asso
Carex pendula Huds.
Cyperus rotundus L.
Eleocharis palustris (L.) Roem. & Schult. subsp. *palustris*
Schoenoplectus lacustris (L.) Palla
Scirpoides holoschoenus (L.) Soják

CYTINACEAE
Cytinus hypocistis (L.) L.
Cytinus ruber Fourr. ex Fritsch

DIOSCOREACEAE
Dioscorea communis (L.) Caddick & Wilkin

DIPSACACEAE
Dipsacus fullonum L. subsp. *fullonum*
Sixalix atropurpurea (L.) Greuter & Burdet

ERICACEAE
Arbutus unedo L.
Erica arborea L.

EUPHORBIACEAE
Chrozophora tinctoria (L.) A. Juss.
Euphorbia ceratocarpa Ten.
Euphorbia characias L.
Euphorbia dendroides L.
Euphorbia helioscopia L. subsp. *helioscopia*
Euphorbia meuselii Geltman
Euphorbia peplus L.
**Euphorbia prostrata* Aiton
Euphorbia rigida M. Bieb.
Mercurialis annua L.
**Ricinus communis* L.

FABACEAE
Anthyllis vulneraria L. subsp. *maura* (Beck) Maire
Astragalus boeticus L.
Astragalus echinatus Murray
Astragalus hamosus L.
Bituminaria bituminosa (L.) C.H.Stirt.
Cytisus infestus (C. Presl) Guss. subsp. *infestus*
Cytisus villosus Pourr.
Emerus major Mill. subsp. *major*
Ervilia hirsuta (L.) Opiz
Hippocrepis multisiliquosa L.
Lathyrus annuus L.
Lathyrus cicera L.
Lathyrus clymenum L.
Lathyrus ochrus (L.) DC.
Lathyrus sphaericus Retz.
Lathyrus sylvestris L. subsp. *sylvestris*
Lotus biflorus Desr.
Lotus edulis L.
Lotus hispidus DC.
Lotus ornithopodioides L.
Lupinus albus L.
Medicago coronata (L.) Bartal.
Medicago doliata Carmign.

Medicago intertexta (L.) Mill.
Medicago minima (L.) L.
Medicago murex Willd.
Medicago orbicularis (L.) Bartal.
Medicago polymorpha L.
Medicago rugosa Desr.
Medicago truncatula Gaertn.
Onobrychis caput-galli (L.) Lam.
Ononis diffusa Ten.
Ononis mitissima L.
Ornithopus compressus L.
Pisum sativum L.
Scorpiurus subvillosus L.
Spartium junceum L.
Sulla coronaria (L.) Medik.
Trifolium angustifolium L.
Trifolium arvense L. subsp. *arvense*
Trifolium bivonae Guss.
Trifolium campestre Schreb.
Trifolium fragiferum L. subsp. *fragiferum*
Trifolium incarnatum L. subsp. *molinerii* (Balb. ex Hornem.) Ces.
Trifolium lappaceum L.
Trifolium nigrescens Viv. subsp. *nigrescens*
Trifolium pallidum Waldst. & Kit.
Trifolium physodes M. Bieb.
Trifolium pratense L. subsp. *pratense*
Trifolium repens L.
Trifolium resupinatum L
Trifolium scabrum L.
Trifolium stellatum L.
Trifolium subterraneum L. subsp. *subterraneum*
Trigonella italica (L.) Coulot & Rabaute
Trigonella sulcata (Desf.) Coulot & Rabaute
Tripodion tetraphyllum (L.) Fourr.
Vicia bithynica (L.) L.
Vicia dasycarpa Ten.
Vicia disperma DC.
Vicia hybrida L.
Vicia sativa L.

FAGACEAE
Castanea sativa Miller
Quercus ilex L. subsp. *ilex*

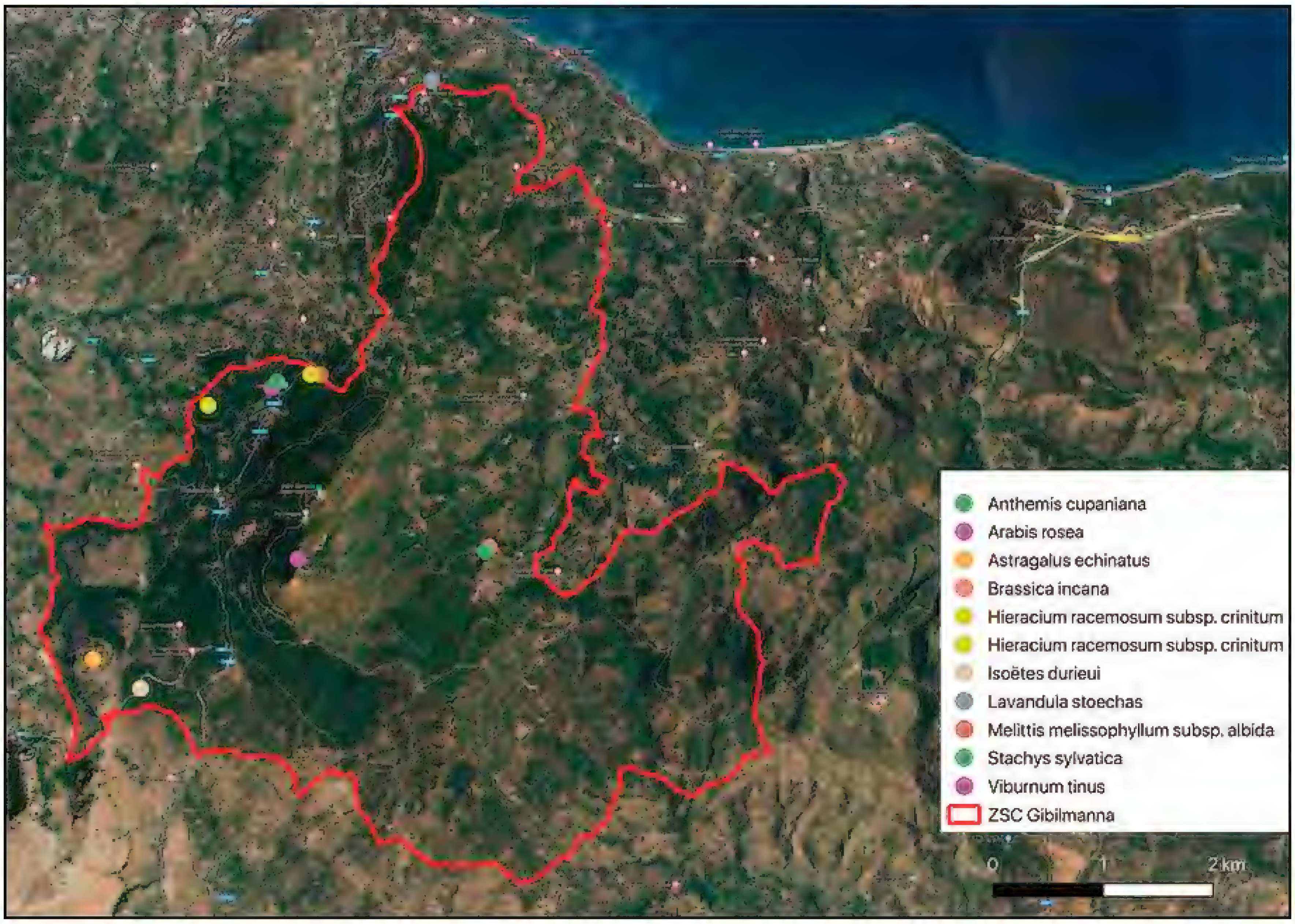
● Anthemis cupaniana
● Arabis rosea
● Astragalus echinatus
● Brassica incana
● Hieracium racemosum subsp. crinitum
● Hieracium racemosum subsp. crinitum
● Isoëtes durieui
● Lavandula stoechas
● Melittis melissophyllum subsp. albida
● Stachys sylvatica
● Viburnum tinus
▭ ZSC Gibilmanna
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Figure 11. Bosco di Gibilmanna: local distribution of rare taxa or with a phytogeographical interest.

Quercus suber L.
Quercus virgiliana (Ten.) Ten.

GENTIANACEAE
Blackstonia perfoliata (L.) Huds. subsp. *intermedia* (Ten.) Zeltner
Centaurium erythraea Rafin subsp. *erythraea*
Centaurium grandiflorum (Pers.) Ronniger subsp. *grandiflorum*
Centaurium maritimum (L.) Fritsch

GERANIACEAE
Erodium ciconium (L.) L'Her.
Erodium cicutarium (L.) L'Her.
Erodium malacoides (L.) L'Her. subsp. *malacoides*
Geranium dissectum L.
Geranium lucidum L.
Geranium molle L.
Geranium purpureum Vill.
Geranium robertianum L.
Geranium rotundifolium L.

HYPERICACEAE
Hypericum perfoliatum L.
Hypericum perforatum L. subsp. *perforatum*

IRIDACEAE
Crocus longiflorus Raf.
Gladiolus byzantinus Mill.
Gladiolus italicus Mill.
Hermodactylus tuberosus (L.) Mill.
**Iris germanica* L.
Juno planifolia (Mill.) Asch.
Moraea sisyrinchium (L.) Ker Gawl.
Romulea bulbocodium (L.) Sebast. & Mauri
Romulea columnae Sebast. & Mauri

JUNCACEAE
Juncus bufonius L.
Juncus effusus L. subsp. *effussus*
Juncus inflexus L. subsp. *inflexus*

LAMIACEAE
Clinopodium nepeta (L.) Kuntze subsp. *nepeta*
Clinopodium vulgare L. subsp. *arundanum* (Boiss.) Nyman
Lamium amplexicaule L.
Lamium bifidum Cirillo subsp. *bifidum*
Lavandula stoechas L. subsp. *stoechas*
Marrubium vulgare L.
Melissa officinalis L. subsp. *officinalis*
Melittis melissophyllum L. subsp. *albida* (Guss.) P.W. Ball.
Mentha aquatica L. subsp. *aquatica*
Mentha pulegium L. subsp. *pulegium*
Micromeria graeca (L.) Benth. ex Rchb. subsp. *graeca*
Micromeria nervosa (Desf.) Benth.
Origanum vulgare L. subsp. *viridulum* (Martin-Donos) Nyman
Prunella laciniata (L.) L.
Prunella vulgaris L. subsp. *vulgaris*
Pseudodictamnus hispanicus (L.) Salmaki & Siadati
Salvia clandestina L.
**Salvia microphylla* Kunth
Salvia verbenaca L.
Stachys arvensis (L.) L.
Stachys germanica L. var. *dasyanthes* (Raf.) Arcang.
Stachys major (L.) Bartolucci & Peruzzi
Stachys ocymastrum (L.) Briq.
Stachys romana (L.) E.H.L.Krause
Stachys sylvatica L.
Teucrium chamaedrys L. subsp. *chamaedrys*
Teucrium siculum (Raf.) Guss. subsp. *siculum*

LAURACEAE
Laurus nobilis L.

LINACEAE
Linum strictum L.
Linum tryginum L.
Linum usitatissimum L. subsp. *angustifolium* (Huds.) Thell.

LYTHRACEAE
Lythrum junceum Banks & Sol.

MALVACEAE
Malva cretica Cav. subsp. *cretica*
Malva nicaeensis All.
Malva olbia (L.) Alef.
Malva sylvestris L.
Malva trimestris (L.) Salisb.

MORACEAE
Ficus carica L.

NYCTAGINACEAE
**Mirabilis jalapa* L.

OLEACEAE
Fraxinus ornus L. subsp. *ornus*
Olea europaea L. subsp. *oleaster* (Hoffmanns. & Link) Negodi
Phillyrea latifolia L.

ONAGRACEAE
Epilobium hirsutum L.
Epilobium tetragonum L. subsp. *tetragonum*

ORCHIDACEAE
Anacamptis collina (Banks & Sol. ex Russell) R.M. Bateman, Pridgeon & M.W. Chase
Anacamptis laxiflora (Lam.) R.M. Bateman, Pridgeon & M.W. Chase
Anacamptis longicornu (Poir.) R.M. Bateman, Pridgeon & M.W. Chase
Anacamptis papilionacea (L.) R. M. Bateman, Pridgeon & M.W. Chase subsp. *grandiflora* (Boiss.) Kreutz 2007
Anacamptis pyramidalis (L.) Rich.
Barlia robertiana (Loisel.) Greuter
Cephalanthera longifolia (L.) Fritsch
Dactylorhiza romana (Sebast.) Soó subsp. *markusii* (Tineo) Holub
Dactylorhiza romana (Sebast.) Soó subsp. *romana*
Epipactis helleborine (L.) Crantz
Epipactis microphylla (Ehrh.) Sw.
Himantoglossum hircinum (L.) Spreng.
Limodorum abortivum (L.) Sw.
Ophrys apifera Huds.
Ophrys archimedea P. Delforge & M. Walravens
Ophrys bertolonii Moretti subsp. *bertolonii*
Ophrys bombyliflora Link
Ophrys fusca Link subsp. *lupercalis* (Devillers-Tersch. & Devillers) Kreutz
Ophrys lunulata Parl.
Ophrys lutea Cav. subsp. *lutea*
Ophrys lutea subsp. *sicula* (Tineo) Soldano 1993
Ophrys pallida Raf.
Ophrys passionis Sennen subsp. *garganica* E. Nelson
Ophrys speculum Link
Ophrys sphegodes Mill. subsp. *panormitana* (Tod.) Kreutz
Ophrys sphegodes Mill. subsp. *sphegodes*
Ophrys tenthredinifera Willd.
Orchis anthropophora (L.) All.
Orchis brancifortii Biv.
Orchis italica Poir.
Orchis provincialis Balb. ex Lam. & DC.
Serapias cordigera L. subsp. *cordigera*
Serapias lingua L.
Serapias nurrica Corrias subsp. *nurrica*
Serapias vomeracea (Burm. f.) Briq.
Spiranthes spiralis (L.) Chevall.

OROBANCHACEAE
Bellardia trixago (L.) All.
Bellardia viscosa (L.) Fisch. & C.A. Mey
Odontites vernus (Bellardi) Dumort. subsp. *siculus* (Guss.) P.D. Sell
Orobanche caryophyllacea Sm.
Orobanche crenata Forssk.
Orobanche hederae Vaucher ex Duby
Phelipanche lavandulacea (Rchb.) Pomel subsp. *lavandulacea*
Phelipanche mutelii (F.W. Schultz) Reut.
Phelipanche nana (Reut.) Soják
Phelipanche ramosa (L.) Pomel

OXALIDACEAE
**Oxalis articulata* Savigny
**Oxalis pes-caprae* L.

PAEONIACEAE
Paeonia mascula (L.) Miller subsp. *russoi* (Biv.) Cullen & Heywood

PAPAVERACEAE
Fumaria capreolata L. subsp. *capreolata*
Fumaria flabellata Gasp.
Papaver dubium L.
Papaver hybridum L
Papaver rhoeas L. subsp. *rhoeas*
Papaver rhoeas L. var. *himerense* Raimondo & Spadaro
Papaver setigerum DC.

PLANTAGINACEAE
Antirrhinum majus L. subsp. *tortuosum* (Bosc ex Lam.) Rouy
Callitriche obtusangula Le Gall
Callitriche stagnalis Scop.
Kickxia spuria (L.) Dumort. subsp. *integrifolia* (Brot.) R. Fern.
Linaria purpurea (L.) Mill.
Linaria reflexa (L.) Desf. subsp. *reflexa*
Misopates orontium (L.) Rafin.
Plantago afra L. subsp. *afra*
Plantago lagopus L.
Plantago lanceolata L.
Plantago major L.

Plantago serraria L.
Veronica anagallis-aquatica L. subsp. *anagallis-aquatica*
Veronica cymbalaria Bodard
Veronica persica Poir.

PLUMBAGINACEAE
Plumbago europaea L.

POACEAE
Aira caryophyllea L.
Ampelodesmos mauritanicus (Poir.) T. Durand & Schinz
Anisantha madritensis (L.) Nevski subsp. *madritensis*
Anisantha sterilis (L.) Nevski
Anisantha tectorum (L.) Nevski
Anthoxanthum odoratum L.
Arundo donax L.
Arundo plinii Turra
Avena fatua L.
Avena sativa L.
Brachypodium distachyon (L.) P. Beauv.
Brachypodium retusum (Pers.) Beauv. (Host) Roem. & Schult.
Brachypodium sylvaticum (Hudson) P.Beauv.
Briza maxima L.
Bromus hordeaceus L. subsp. *hordeaceus*
Catapodium rigidum (L.) C.E. Hubb. subsp. *rigidum*
Cynodon dactylon (L.) Pers.
Cynosurus cristatus L.
Cynosurus echinatus L.
Dactylis glomerata L. subsp. *glomerata*
Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman
Dasypyrum villosum (L.) P. Candargy
Eragrostis cilianensis (All.) Vignolo ex Janch. subsp. *cilianensis*
Festuca ligustica (All.) Bertol.
Festuca myuros L. subsp. *myuros*
Hordeum bulbosum L.
Hordeum murinum L. subsp. *leporinum* (Link) Arcang
Hyparrhenia hirta (L.) Stapf subso. *hirta*
Koeleria splendens Presl subsp. *splendens*
Lagurus ovatus L. subsp. *ovatus*
Lolium perenne L.
Lolium rigidum Gaudin
Melica ciliata L. subsp. *ciliata*
Oloptum miliaceum (L.) Röser & H.R. Hamasha
Paspalum distichum L.
Phalaris paradoxa L.
Poa annua L.
Poa infirma Kunth
Poa sylvicola Guss.
Poa trivialis L.
Rostraria cristata (L.) Tzvelev
Sorghum halepense (L.) Pers.
Stipellula capensis (Thunb.) Röser & H.R. Hamasha
Triticum vagans (Jord. & Fourr.) Greuter

POLYGONACEAE
Polygonum aviculare L. subsp. *aviculare*
Rumex bucephalophorus L. subsp. *bucephalophorus*
Rumex crispus L.
Rumex cristatus DC.
Rumex thyrsoides Desf.

PORTULACACEAE
Portulaca oleracea L.

PRIMULACEAE
Cyclamen hederifolium Aiton subsp. *hederifolium*
Cyclamen repandum Sm. subsp. *repandum*
Lysimachia arvensis (L.) U. Manns & Anderb. subsp. *arvensis*
Samolus valerandi L.

RANUNCULACEAE
Anemone hortensis L. subsp. *hortensis*
Clematis cirrhosa L.
Clematis vitalba L.
Delphinium halteratum Sm. subsp. *halteratum*
Ficaria verna Huds. subsp. *verna*
Nigella damascena L.
Ranunculus bulbosus L. subsp. *aleae* (Willk.) Rouy & Foucaud
Ranunculus bulbosus L. subsp. *neapolitanus* (Ten.) H. Lindb.
Ranunculus bullatus L.
Ranunculus muricatus L.
Thalictrum calabricum Spreng.

RESEDACEAE
Reseda alba L.

RHAMNACEAE
Rhamnus alaternus L. subsp. *alaternus*

ROSACEAE
Agrimonia eupatoria L. subsp. *eupatoria*
Crataegus monogyna Jacq.
Fragaria vesca L. subsp. vesca
Malus sylvestris (L.) Mill.
Mespilus germanica L.
Potentilla reptans L.
Poterium sanguisorba L. subsp. *sanguisorba*
Prunus spinosa L. subsp. *spinosa*
Pyrus communis L. subsp. *communis*
Pyrus spinosa Forssk.
Rosa canina L.
Rosa micrantha Borrer ex Sm.
Rosa sempervirens L.
Rubus ulmifolius Schott

RUBIACEAE
Asperula aristata L. f. subsp. *scabra* Nyman
Galium aparine L.
Galium lucidum All.
Galium verrucosum Huds.
Galium verum L. subsp. *verum*
Rubia peregrina L.
Sherardia arvensis L.
Valantia muralis L.

RUTACEAE
Ruta chalepensis L.

SALICACEAE
Salix pedicellata Desf.

SANTALACEAE
Osyris alba L.

SAPINDACEAE
Acer campestre L.,

SAXIFRAGACEAE
Saxifraga bulbifera L.
Saxifraga tridactylites L.

SCROPHULARIACEAE
Scrophularia peregrina L.
Verbascum sinuatum L.
Verbascum thapsus L. subsp. *thapsus*

SIMAROUBACEAE
**Ailanthus altissima* (Mill.) Swingle

SMILACACEAE
Smilax aspera L.

SOLANACEAE
Mandragora autumnalis Bertol.
Solanum nigrum L.

THYMELAEACEAE
Daphne gnidium L.
Daphne laureola L.

TYPHACEAE
Typha angustifolia L.
Typha latifolia L.

ULMACEAE
Ulmus minor Mill. subsp. *canescens* (Melville) Browicz & Ziel.

URTICACEAE
Parietaria judaica L.
Parietaria lusitanica L. subsp. *lusitanica*
Urtica dioica L. subsp. *dioica*
Urtica membranacea Poir.
Urtica pilulifera L.

VALERIANACEAE
Centranthus ruber (L.) DC. subsp. *ruber*
Fedia graciliflora Fisch. & C.A. Mey.
Valerianella eriocarpa Desv.

VERBENACEAE
Verbena officinalis L.

VIBURNACEAE
Viburnum tinus L. subsp. *tinus*

VIOLACEAE
Viola alba Besser subsp. *dehnhardtii* (Ten.) W. Becker
Viola odorata L.

ZYGOPHYLLACEAE
Tribulus terrestris L.

CONCLUSIONS

This study allowed to survey the vascular flora of the Gibilmanna and Cefalù woods, an area classified as a Special Area of Conservation (S.A.C.). It provides new data on a territory that had not previously been the subject of specific floristic investigations, having a certain phytogeographical interest for its location and ecological features.

Besides, the results obtained show a low incidence of exotic plants (23 species), mostly restricted to cultivated areas and to the most disturbed sites located near country houses and roads.

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Contributions to the research of ecological gradients in the treatment of floristic data (Oran, Algeria)

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ABSTRACT The factorial analysis of the correspondence from the "Minitab" software carried out on the floristic inventoried species at four different stations in Oran region (Algeria) made it possible to highlight interesting information on the numerous ecologic variations which evolve over time in a certain environment. This biostatistical treatment has also revealed a certain number of gradients (environmental disturbances) underlying the different axes of the factorial planes of the stations. These factors are mainly related to anthropogenic actions (crops, nitrates, etc.) which often lead to frequent therophytisation. To these are added other natural factors such as salinity and steppisation.

KEY WORDS Multivariate analysis; Ecological factors; Gradients; Algeria.

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INTRODUCTION

The pre-forest formations as well as the steppe areas are often exposed to numerous ecologic variations which evolve over time.

For almost a quarter of a century, factorial correspondence analysis (CFA) has been widely used in all areas of ecology, in particular in phytoecology (Bonnin & Tatoni, 1990). According to these authors, factor analysis of correspondence has been the subject to date of many considerations regarding its use in ecology.

The variables that can intervene are numerous, leading us to perform an interpretation which is essentially based on statistical analysis. Benzekri's (1970) work on factorial correspondence analysis (AFC) has helped to advance it. This analysis is used in particular in phytoecology and phytosociology and was developed by a certain number of authors, among them: Dagnelie (1960, 1965, 1970), Cordier (1965), Gounot (1969), Perrichaud & Bonnin (1993), Benzekri (1970, 1990), Celles (1975), Chessel & Bournaud (1987), Loisel et al. (1990), El-Hamrouni (1992), Benabadji et al. (2004), Aboura et al. (2007), and Merzouk (2010).

The method in question individualizes and characterizes plant associations and is the best suited to gather and, above all, to identify the responsible ecological factor (from the most distant species on the axes).

The objective of this study is to try to study the floristic diversity which is governed by ecological factors at the level of some matorral and anthropozoogenic stations that we will try to bring out from this biostatistical approach.

In particular, we studied what are the main ecological variations obtained through the analysis of the factors and what information they can provide in our different geographical stations and on the different factor plans.

MATERIAL AND METHODS

Study area

The study area includes different stations, chosen from a stratified sampling, located in Oran District, Algeria. In particular, this study area is located in the Wilaya of Tlemcen, along the road Tlemcen Maghnia RN 35 (Fig. 1). It extends over an area of 9017.59 km², rises to an approximate altitude of 214 meters a.s.l. and is between 34°25' and 35°25' north latitude and 0°55' and 2°30' west longitude.

The study area choice was guided by the presence of halophyte plant formations. Four stations were stratified, which may seem insufficient in a territory spanning such a large area.

The statistical processing from the "Minitab 16" software took into account the plant species after having coded them for readings from each station. We then placed them in a table in Excel (with the statements in rows and the species in columns).

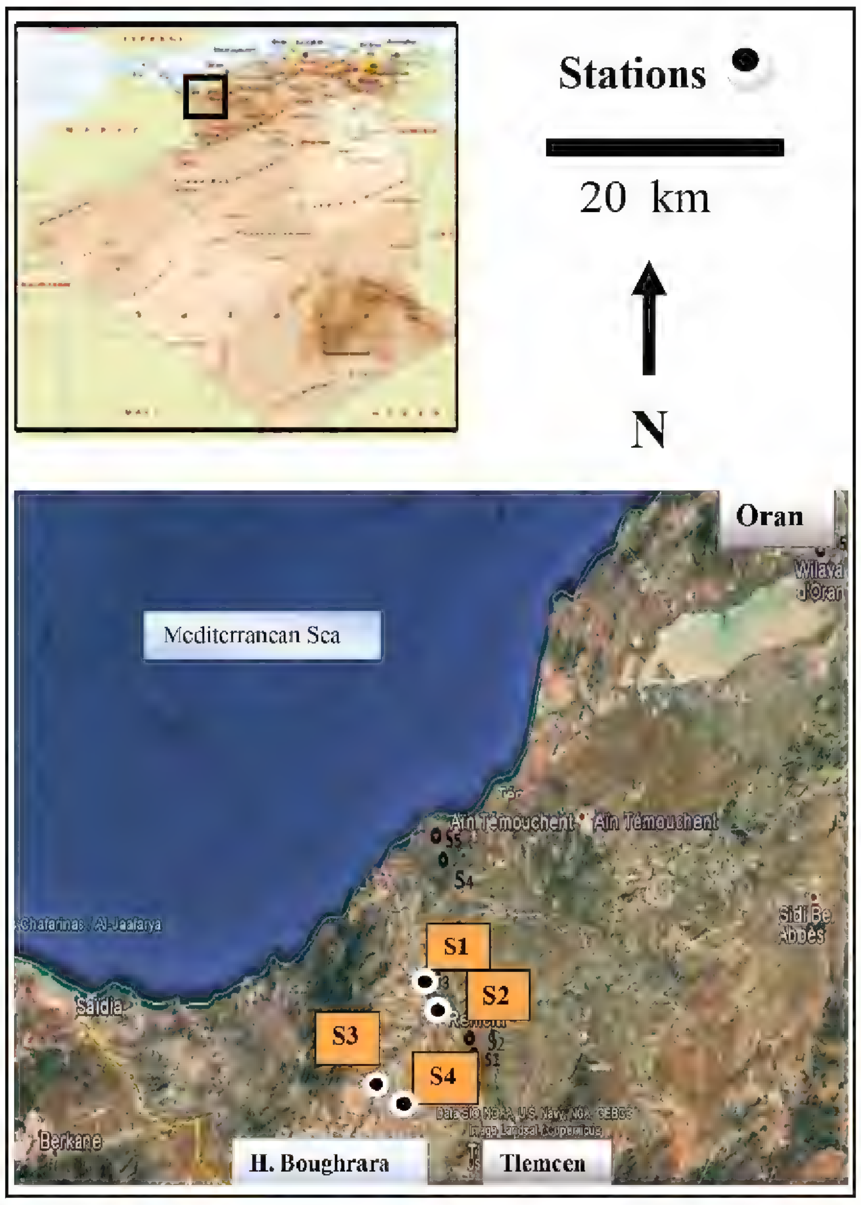


Figure 1. The study area.

One of the fundamental interests of this method is the simultaneous representation in the same space and in a symmetrical way of the surveys and the species so that each species is localized within the group of surveys to which it is most closely linked to (Lacoste, 1972).

Only the abundance-dominance coefficient is used. The tables constitute the matrix from which the distance calculations are made.

RESULTS AND DISCUSSION

Station 1 (Figs. 2, 3, Tables 1–4)

Axis 1

We notice a large central grouping with species of weak ecological significance. An increasing post-cultural gradient that goes from the positive side to the negative side of the axis. We also noticed an increasing gradient of salinity going from the negative side to the positive side.

Axis 2

Here too, a large central groups together species with weak ecological significance. An increasing pre-forest/scrub gradient (*Asparagus albus* -2.00862) which goes from the positive side to the negative side of the axis. We also notice an increasing crop gradient (*Phalaris bulbosa* +2.36252) going from the negative side to the positive side of the axis.

Axis 3

An increasing xericity gradient, presence of thorny species (*Eryngium tricuspidatum* -2.93640) which goes from the positive side to the negative side of the axis. We also notice an increasing grazing gradient going from the negative side to the positive side of the axis.

Station 2 (Figs. 4, 5, Tables 5–8)

Axis 1

An increasing matorral gradient (*Echium pycnanthum* -2.359) is well signified which goes from the positive side to the negative side of the axis. On

stations	Axis 1	Axis 2	Axis 3
own value	1.4720	0.8901	0.6379
inertia	0.491	0.297	0.213

Table 1. Station 1: inertia and eigenvalue of the axes.

Negative side	Positive side
Phalaris bulbosa (-2.91336) *Plantago psyllium* (-2.35990)	*Atriplex halimus* (+0.52104) *Calycotome spinosa* (+0.52104)

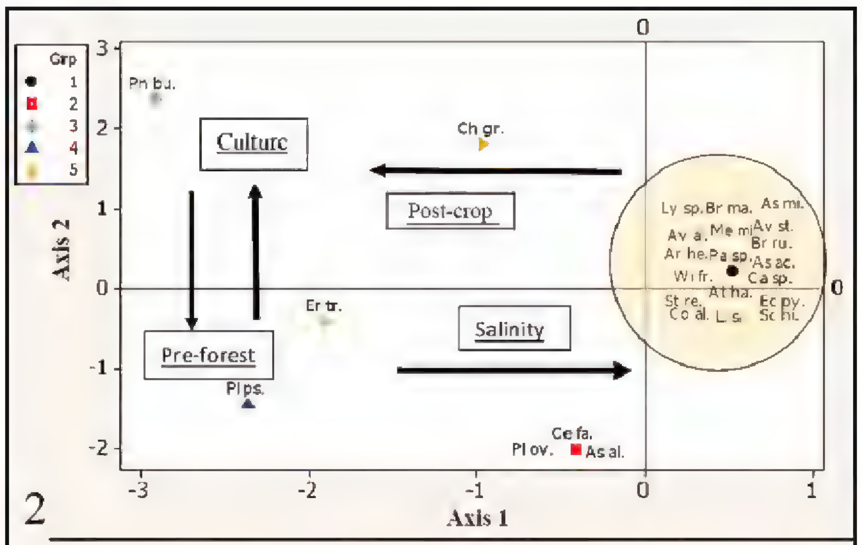
Table 2. Station 1, axis 1: coordinates species.

Negative side	Positive side
Asparagus albus (-2.00862) *Plantago ovata* (-2.00862) *Ceratocephalus faluatus* (-2.91336)	*Phalaris bulbosa* (+2.36252) *Chrysanthemum grandiflorum* (+1.80770)

Table 3. Station 1, axis 2: coordinates species.

Negative side	Positive side
Eryngium tricuspidatum (-2.93640)	*Phalaris bulbosa* (+1.15983)

Table 4. Station 1, axis 3: coordinates species.



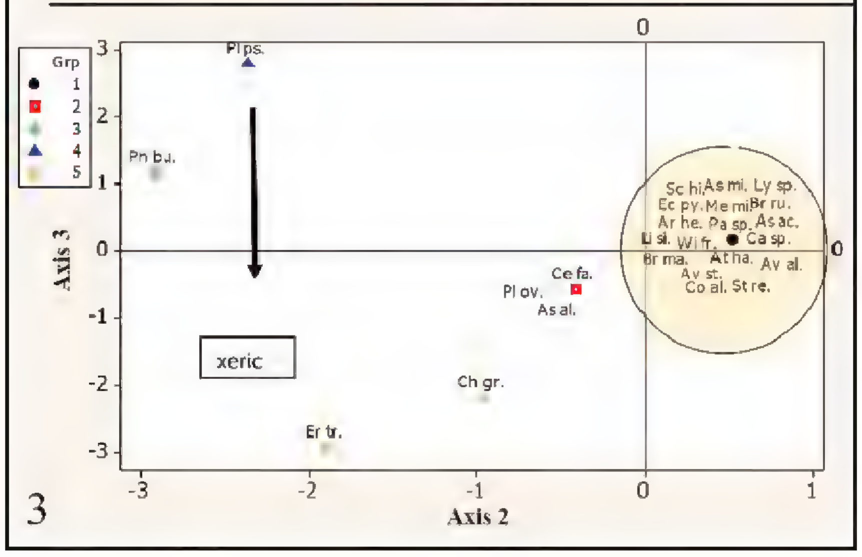


Figure 2. Factorial plan of species Station 1 (Axis 1-Axis 2).
Figure 3. Factorial plan of species Station 1 (Axis 1-Axis 3).

the other hand, we notice an increasing gradient of salinity (*Atriplex halimus* +0.52104) going from the negative side to the positive side.

Axis 2

An increasing gradient after the use of crops (*Avena sterilis* -2.00862) going from the positive side to the negative side of the axis. The other side is characterized by an increasing gradient of overgrazing (*Plantago ovata* +2.36252) going from the negative side to the positive side.

Axis 3

An increasing salinity gradient (*Stipa tortilis* -2.93640) which goes from the positive side to the negative side of the axis. The other side is marked by an increasing gradient of matorral (*Echium pycnanthum* +2.78060) going from the negative side to the positive side.

Station 3 (Figs. 6, 7, Tables 9–12)

Axis 1

An increasing nitrates gradient (*Phalaris bulbosa*, *Medicago falcata* -1.64018) which goes from the positive side to the negative side of the axis. On the opposite side of the axis an increasing Steppe gradient (*Artemisia herba-alba* +1.13202) appears going from the negative side to the positive side.

Axis 2

An increasing salinity gradient (*Atriplex halimus* -0.98141) which goes from the positive side to the negative side of the axis. The positive side is marked by an increasing gradient of CaSO4 (*Lygeum spartum* +1.88103) and anthropization (*Plantago ovata* / culture +1.85169) going from the negative side to the positive side.

Axis 3

An increasing post-cultural gradient (*Bromus rubens* -2.38129) which goes from the positive side to the negative side of the axis. On the positive side an increasing gradient of overgrazing (*Ziziphus lotus* +1.76932) going from the negative side to the positive side.

stations	Axis 1	Axis 2	Axis 3
own value	1.4623	1.1875	0.3501
inertia	0.487	0.396	0.117

Table 5. Station 2: inertia and eigenvalue of the axes.

Negative side	Positive side
Echium pycnanthum (-2.35990)	*Atriplex halimus* (+ 0.52104) *Withania frutescens* (+ 0.52104)

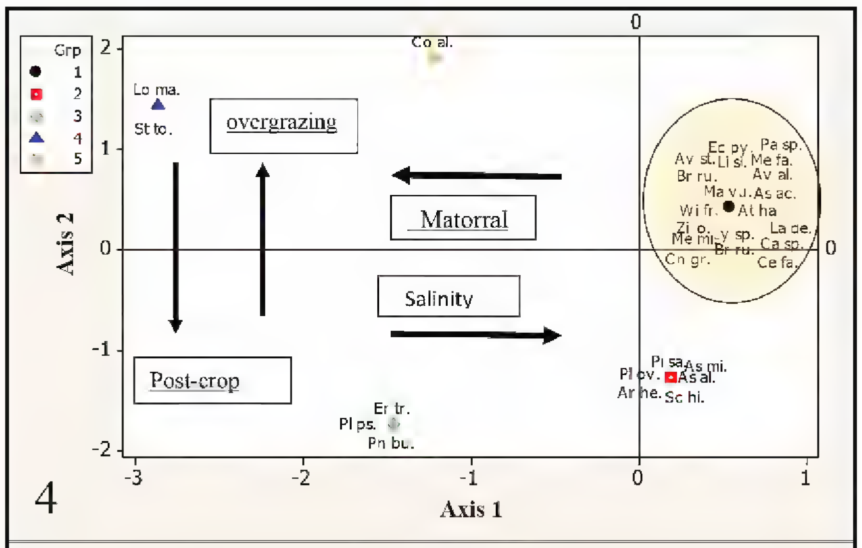
Table 6. Station 2 axis 1: coordinates species.

Negative side	Positive side
Avena sterilis (-2.00862) *Linaria simplex* (-2.00862) *Pisum sativum* (-2.00862)	*Plantago ovata* (+2.36252)

Table 7. Station 2 axis 2: coordinates species.

Negative side	Positive side
Stipa tortilis (-2.93640)	*Echium pycnanthum* (+ 2.78060)

Table 8. Station 2 axis 3: coordinates species.



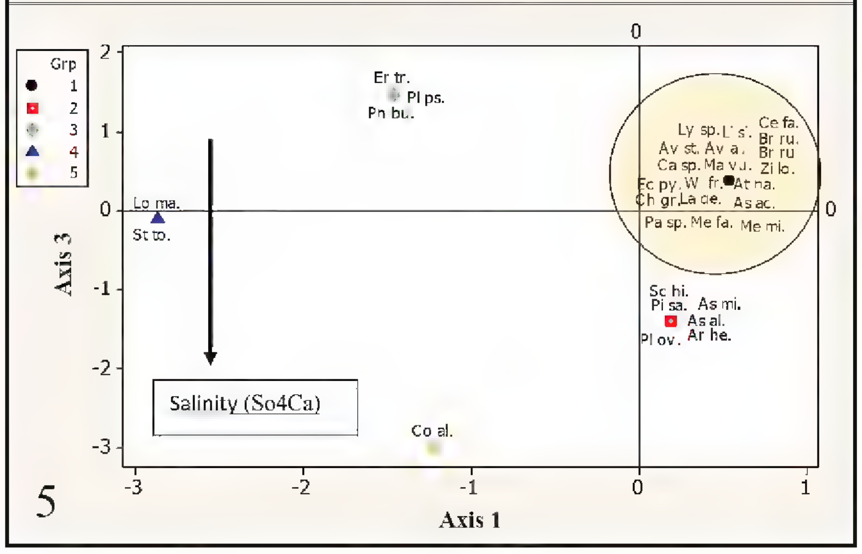


Figure 4. Factorial plan of species Station 2 (Axis 1-Axis 2).
Figure 5. Factorial plan of species Station 2 (Axis 1-Axis 3).

stations	Axis 1	Axis 2	Axis 3
own value	1.5671	0.4450	0.9878
inertia	0.522	0.329	0.148

Table 9. Station 3: inertia and eigenvalue of the axes.

Negative side	Positive side
Phalaris bulbosa (-1.64018) *Medicago falcate* (-1.64018)	*Artemisia herba-alba* (+1.13202) - *Asparagus acutifolius* (+1.13202)

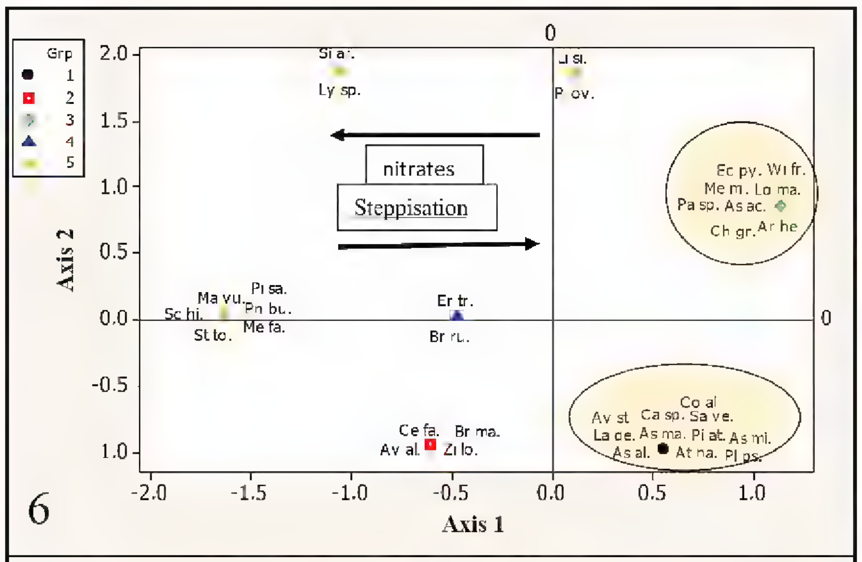
Table 10. Station 3, axis 1: coordinates species.

Negative side	Positive side
Atriplex halimus (-0.98141)	*Lygeum spartum* (+1.88103) *Plantago ovata* (+1.85169)

Table 11. Station 3, axis 2: coordinates species.

Negative side	Positive side
Bromus rubens (-2.38129) *Eryngium tricuspidatum*	*Ziziphus lotus* (+1.76932) *Avena alba*

Table 12. Station 3, axis 3: coordinates species.



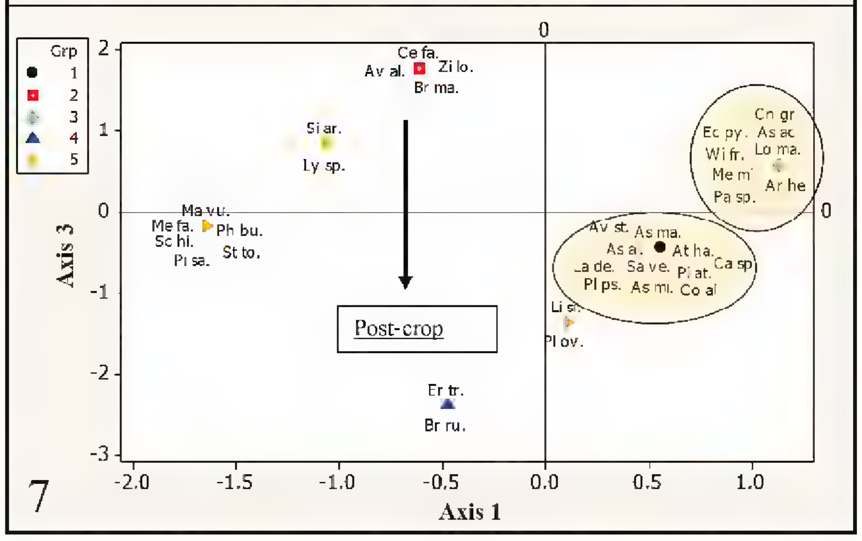


Figure 6. Factorial plan of species Station 3 (Axis 1-Axis 2).
Figure 7. Factorial plan of species Station 3 (Axis 1-Axis 3).

Station 4 (Figs. 8, 9, Tables 13–16)

Axis 1

An increasing gradient of grazed steppe (*Artemisia herba-alba* -1.69176) which goes from the positive side to the negative side of the axis. An increasing gradient of pre-forest (*Asparagus albus* +1.51572) exists which goes from the negative side to the positive side.

Axis 2

An increasing saline steppe gradient (*Atriplex halimus* and *Withania frutescens* -1.06156) which goes from the positive side to the negative side of the axis. An increasing gradient of pre-forest exists which goes from the negative side to the positive side.

Axis 3

An increasing lawn gradient (*Echium pycanthum* and *Bromus madritensis* -1.69551) which goes from the positive side to the negative side of the axis. An increasing gradient of pre-forest exists which goes from the negative side to the positive side.

CONCLUSIONS

This peculiarity of seeing the species of the scrub mixed between them can be perplexing but the factorial treatment was able to partially elucidate on this distribution of undiversified plant formations.

It should be noted that the large area appearing in the middle of the axes includes companion species or with feeble ecological significance.

These treatments, among others by factorial analysis of correspondences on the four stations (with contiguous plots), highlight the classic factors that can characterize these open environments where various species can interfere, as those of the scrub (*Asparagus albus*, *Asparagus acutifolius*, *Withania frutescens*, *Pistacia atlantica*, *Ziziphus lotus*, *Calycotome spinosa*, *Lavandula dentata*), those of the steppes (*Lygeum spartum*) and those of

stations	**Axis 1**	**Axis 2**	**Axis 3**
own value	1.1759	0.9958	0.8283
inertia	0.392	0.332	0.276

Table 13. Station 4: inertia and eigenvalue of the axes.

Negative side	Positive side
Artemisia herba-alba (-1.69176) - *Asparagus acutifolius* (-1.69176)	*Asparagus albus* (+1.51572) *Plantago psyllium* (+1.51572)

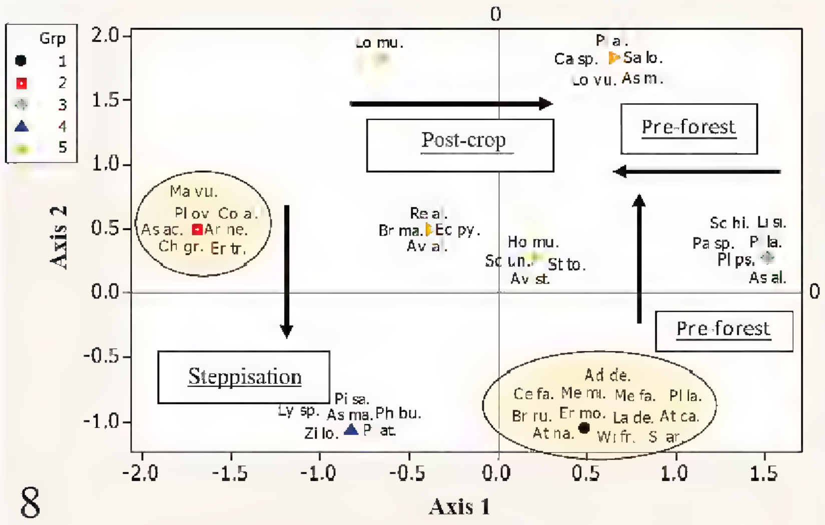
Table 14. Station 4 axis 1: coordinates species.

Negative side	Positive side
Atriplex halimus (-1.06156) *Withania frutescens* (-1.06156)	*Asphodelus microcarpus* (+1.83578) *Lobularia marítima* (+1.83578)

Table 15. Station 4 axis 2: coordinates species.

Negative side	Positive side
Echium pycanthum (-1.69551) - *Bromus madritensis* (-1.69551)	*Avena sterilis* (+2.11660) *Stipa tortilis* (2.11660)

Table 16. Station 4 axis 3: coordinates species.



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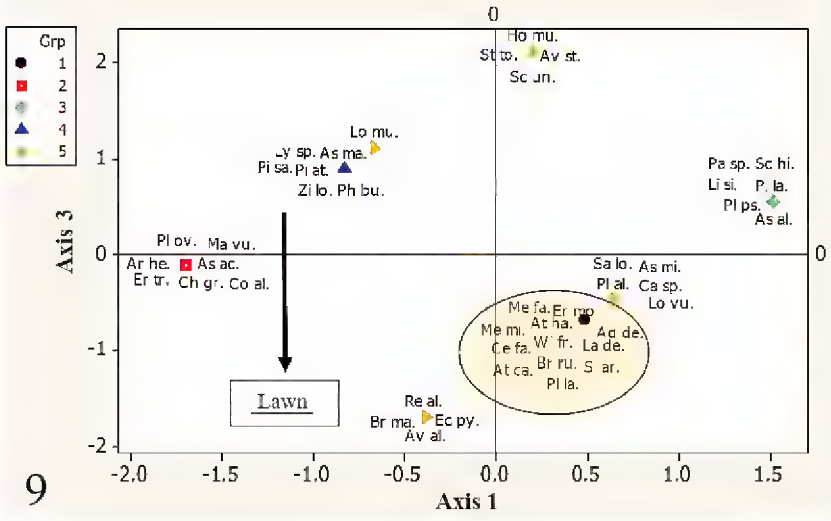

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Figure 8. Factorial plan of species Station 4 (Axis 1-Axis 2).
Figure 9. Factorial plan of species Station 4 (Axis 1-Axis 3).

the salty steppes composed of halophilic or halophyte species (*Atriplex halimus* and *Salsola vermiculata* in particular).

The biotic and abiotic factors, also called gradients in the ecological sense of the term, are often linked to the multiple actions (disturbances) which are exerted on the ecosystem and that seem obvious at least in our case: overgrazing, culture, matorral, salinity, nitrate, xericinity.

In our opinion, it is useful to complete this study by looking for other ecological factors that can be elucidated from factorial axes on other stations and which can improve the understanding of these natural phenomena.

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Reproductive biology of horse mackerel, genus *Trachurus* Rafinesque, 1810 (Perciformes Carangidae), caught in Béni-Saf Bay, W-Mediterranean Sea (Algeria)

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ABSTRACT

This paper gives a description of reproduction of the horse mackerel (genus *Trachurus* Rafinesque, 1810) (Perciformes Carangidae) in the west-south coast of Mediterranean Sea in the Béni-Saf Bay, between November 2015 and October 2016. In total, 488 individual were sampled and 240 (49.18%) were males, 208 (42.62%) were females and 40 (8.20%) were undetermined. Length of individuals varied between 7.1 and 35.5 cm and weight from 5.09 to 343.4g. This work provides values of sizes at first sexual maturity (TL50), that were estimated for males at 155 mm and females 148.5 mm, respectively. The spawning period extends from January to June and the spawning peak occurs from April to July. The factor of condition (K) increased during the sexual resting phase. This factor is weak during the period of reproduction. Coefficient of condition K seems to follow the same pattern as the GSI with high values recorded in spring (M: 3.50 and F: 4.46), (M: 3.00 and F: 3.49), in summer and (M: 1.67 and F: 2.63) in winter, and the lowest values in autumn (M: 0.54 and F: 0.69). The sex-ratio of *Trachurus*, per months, by season and by size classes, shows a dominance of males. The difference in percentage increases in favor of the males during the reproduction period, between February and July. This ratio inverts in favor of females during the rest of the year.

KEY WORDS Horse mackerel; *Trachurus trachurus*; reproduction; Spawning period; Béni-Saf Bay.

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INTRODUCTION

The family Carangidae includes about 25 genera and 200 species distributed world-wide in the temperate and tropical seas; some of them are caught commercially and are valued as table food (Caputo et al, 1996). Data on the karyology of the Carangidae are rather scarce, though this information could be useful not only for cytotaxonomic purposes but also for genome manipulation (Amores et al., 1993). The horse mackerel (genus *Trachurus* Rafinesque, 1810) is a gregarious fish of the Carangidae family. It can be found in circalittoral bottoms and even in the upper bathyal stage (Turki, 1987). It is characterized by a very indented caudal fin and the presence of osseous scutes in the posterior part of the lateral line which accentuate its silvery sheen (Quéro, 1984). The geographical distribution of the horse mackerel *Trachurus* covers the whole platform and slope of the European and African coasts from Norway to the Gulf of Guinea, and the Mediterranean and Black Sea.

Trachurus is a migratory fish and its movements are driven by feeding and spawning requirements (Murta et al., 2008). It can be found close to the bottom.

The study of the reproductive activity through the analysis of certain parameters such as variation of some biological indexes can help us better characterize the reproduction cycle by indicating the period and the strategy of laying of these fish. Several works have been dealing with *Trachurus* all around the world: Barraca, 1964; Letaconnoux, 1951; Ben Salem & Ktari, 1980; Arneri, 1983; Alegria, 1984; Kerstan, 1985a, 1995b; Korichi, 1988; Crim et al., 1990; Eltink, 1991;1992; Ben Salem & Ktari, 1994; Abaunza et al., 1995; Laleye et al., 1995; Karlou-Riga & Economidis, 1996, 1997; Fezzani-Serbaji et al., 2002; Gherram, 2009; Tahari, 2011; Aydin & Erdoğan, 2018.

This paper focuses on the reproductive biology of horse macherel (*Trachurus*) of Béni-Saf Bay with emphasis on reproduction period and size at first sexual maturity to complete gaps in life cycle of this Carangidae and better manage this resource in that part of the Algerien coast.

MATERIAL AND METHODS

Monthly samples of horse mackerel, *Trachurus,* were obtained from commercial landings in Béni-Saf port (Coast Guard checkpoint) (Fig. 1), carried out between November 2015 and October 2016. Total length (TL) was measured to the nearest millimeter, total weight (TW) and weight of the gonads (Wg) to the nearest 0.01 g. These different weights are necessary for determining the gonado-somatic index; in addition, the sexes are determined after dissection. Fish lengths were classified in 1 cm group intervals (Fig. 2) and sex was determined macroscopically based on the morphology and the color of gonads (Mahdi et al., 2018).

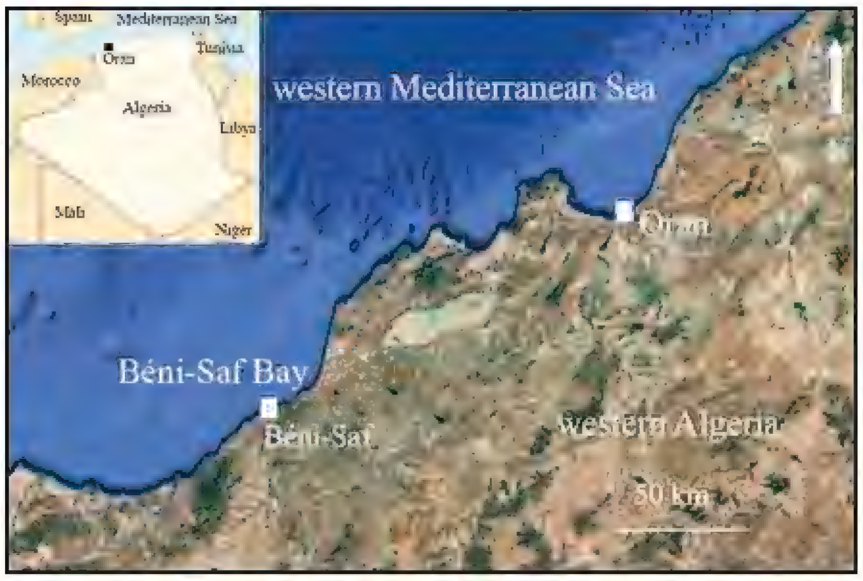

Figure 1. Geographical localization of the study area, Béni-Saf Bay, Algeria.

Sex ratio

It is defined as being the proportion of the male or female individuals compared to the total number of individuals. It also gives an idea on the balance of the sexes within the population. The sex-ratio generally translates the rate of femininity or masculinity of the population:

SR = F/(M+F)*100 (Kartas & Quignard, 1984)
F= number of females; M = number of males.

Gonado somatic index (GSI)

In order to understand the sexual cycle and determine the spawning period the gonado somatic index (GSI) was calculated monthly for females and males. The description of the reproductive cycle of this species and the determination of spawning period were carried by the follow-up of the monthly variations of this index.

GSI = GW/TW × 100 (Htun-Han, 1978)
GW: gonads weight in g; TW: total weight in g.

Coefficient of condition

The coefficient of condition K is defined by the relationship between the weight and the size of fish given by the formula:

$K = TW/TL^3 \times 1000$ (Fulton, 1940)
TW: total weight; TL: total length.

Size of the first sexual maturity

The size of the first sexual maturity ($TL_{50\%}$), which corresponds to the length for which 50% of the individuals are mature, was calculated for our specimens. Considered as ripe, the individuals whose gonads occupy almost the totality of the visceral cavity: for males, the testicles are white milky, for the females, the ovaries are bulky and pinky with visible oocytes through the wall ovaries. For each size class (1 cm) previously defined, we counted mature individuals on one side and immature individuals on the other. Consequently, we determined the relative proportions of each group in relation to the total size of each size class. Subsequently, we determined the values corresponding to the sizes at the first maturity fixed above from an equation whose curve is sigmoid:

$P = 1/1 + e^{-(b+aTL)}$ (1) (Ghorbel et al., 2002)
P: proportion of mature individuals; TL: total length in cm.

The constants a and b are determined by the method of least squares by transforming the equation (1) into linear type:

$\mathrm{Ln}\,(P/1\text{-}P) = b + aL$ (2)

RESULTS

In total, 488 specimens of *Trachurus* were collected (Fig. 2), 240 males (49.18%), 208 females (42.62%) and 40 unsexed (8.20%). The length frequency distribution of the entire population is shown in figure 2, male length range was 10.2 to 34.4 cm, female length range was 9.1 to 35.1 cm while males weight varied between 11.38 and 301.27 g and females' weight varied between 5.09 and 343.41 g.

Sex Ratio

From a 12-month sample represented by a workforce of 488 individuals, we obtained a total masculinity rate of 53.57% for a total femininity rate of 46.43% (Fig. 3).

Overall, in our sample, there is a convergence

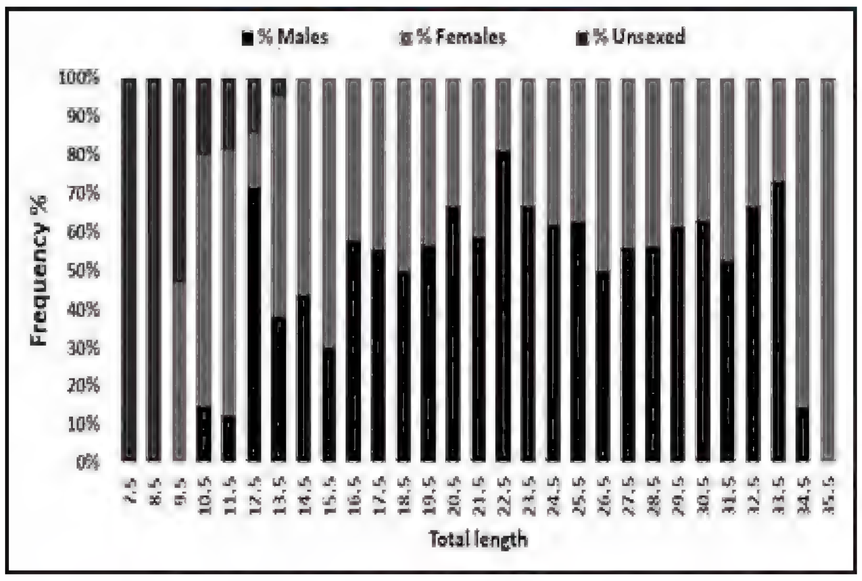

Figure 2. *Trachurus* length frequency distribution of males and females caught in Béni-Saf Bay.

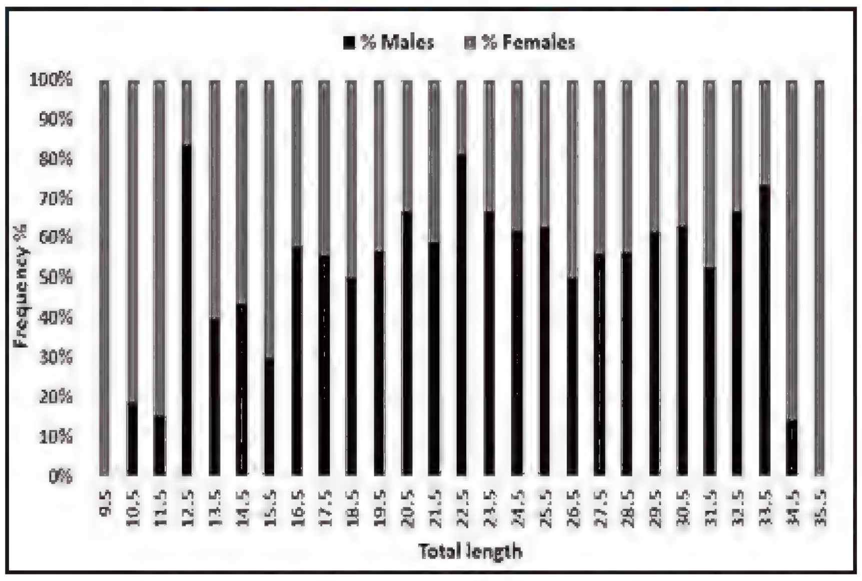

Figure 3. Sex ratio by length size of *Trachurus* caught in Béni-Saf Bay.

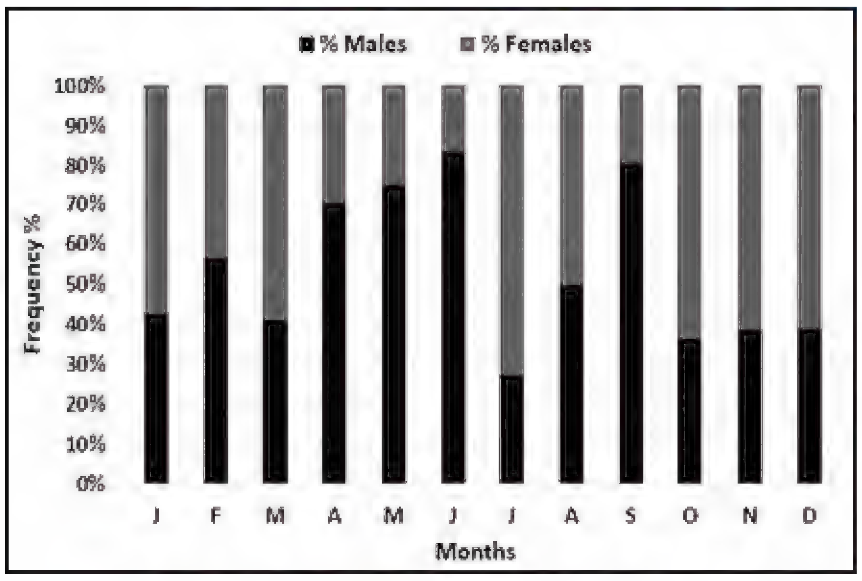

Figure 4. Monthly evolution of Sex ratio of *Trachurus* caught in Béni-Saf Bay.

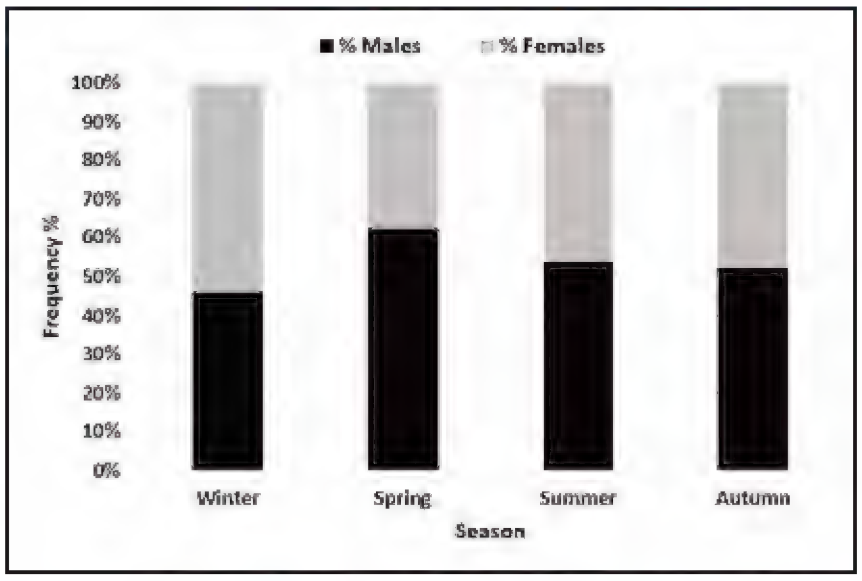

Figure 5. Evolution of Sex ratio by seasons of *Trachurus* caught in Béni-Saf Bay.

between the two sexes ratio with a slight favor of males. In addition, the variations in sex ratio according to size is in favor of females whose total length is less than 16.5. In sizes between 16.5 and 35.5 cm, males outnumbered females, except for size 34.5 cm and 35.5 cm, where females outnumbered males.

Monthly variations of sex-ratio (Fig. 4) reveal that females dominate during the months of January, March, July, October, November and December. And males dominate during February, April, May, June, and September, with a numerical equality in August.

Evolution of sex-ratio related to seasons (Fig. 5) showed that females dominate in winter period while males dominate in spring-summer-autumn period.

Gonado Somatic Index (GSI)

The monthly evolution of the gonado-somatic index (GSI) can help us to determine the spawning period during an annual cycle (Fig. 6), the monthly values of this index varied between 0.43 and 5.87 for females while it varied between 0.30 and 5.08 for males. From January, this index increases for both sexes to attain its maximum in June, after which they begin to gradually decline until they reach their lowest value in October for males and in November for females. This pattern marks an intense sexual activity until early summer in June where this index decreases gradually to reach its lowest values in autumn, marking it as the post spawning period.

Sex-ratio related to the size classes

To investigate the role of small specimens and their contribution to the renewal of the resource, we related GSI to length of individuals (Fig. 7) and it was established that GSI increased simultaneously

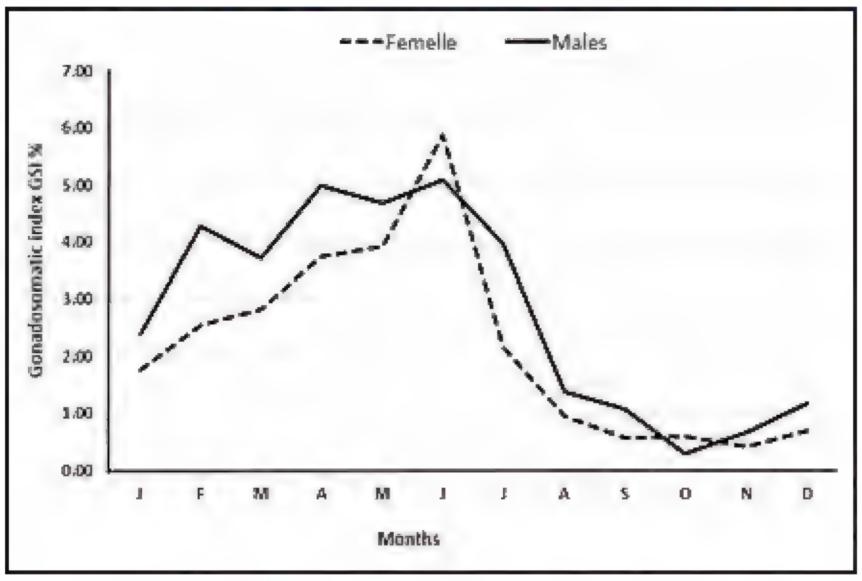

Figure 6. Monthly evolution of GSI for males and females of *Trachurus* caught in Béni-Saf Bay.

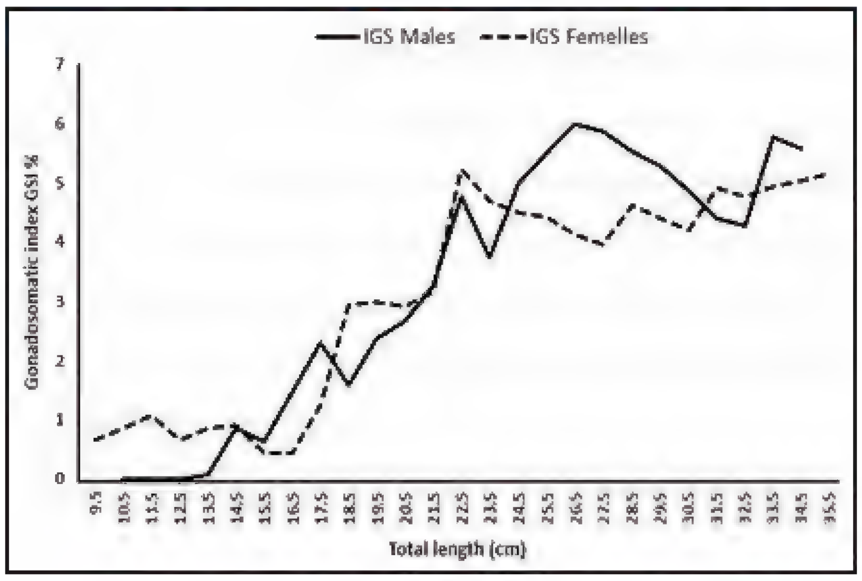

Figure 7. Evolution of GSI related to total length of males and females of *Trachurus* caught in Béni-Saf Bay.

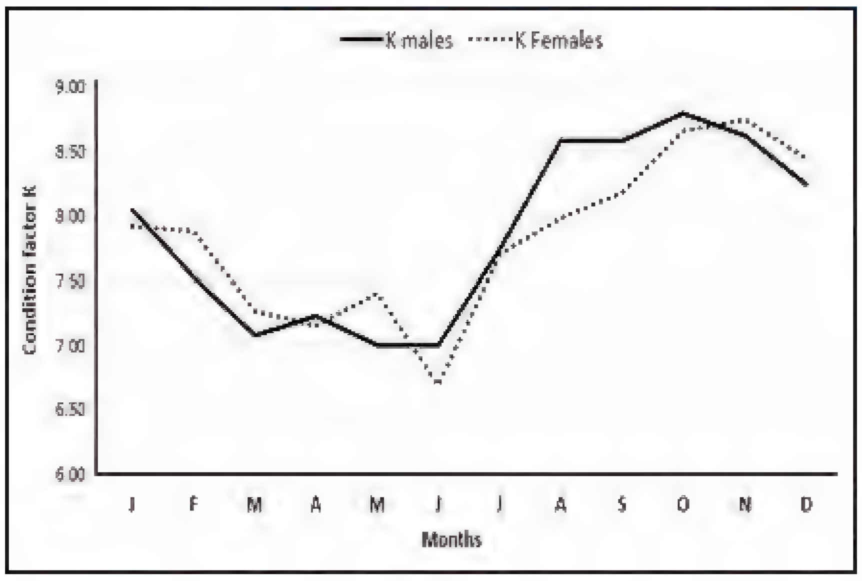

Figure 8. Annually evolution of condition factor K of *Trachurus* males and females caught in Béni-Saf Bay.

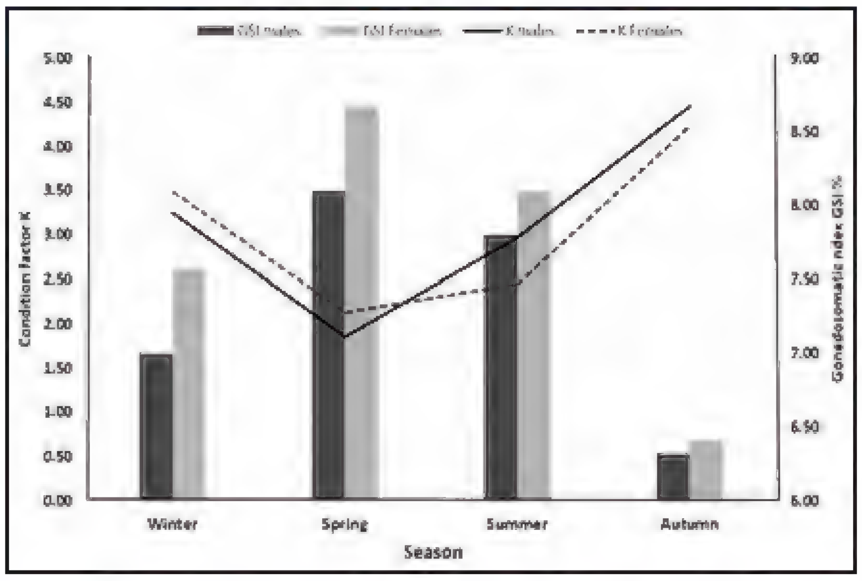

Figure 9. Seasonal evolution of condition factor K and GSI of *Trachurus* males and females caught in Béni-Saf Bay.

in females and males. For males, we recorded a maximum of GSI at 5.995 corresponding to a size 27.5 cm and a minimum of GSI at 0.004 according to 12.5 cm. For females, the GSI maximum value was recorded at 5.23 corresponding to a size of 22.5 cm while the GSI minimal value was recorded for 16.5 cm.

Condition Factor K

The changes observed in the condition factor coefficient seem to be closely but inversely related to the gonado-somatic ratio (GSI), where the two indices are inversely proportional. In fact, during the spawning period the condition factor of the specimens was recorded at its lowest values (7.01 for females and 6.70 for males) and in rest period the same factor records its highest values (8.81 for females and 8.76 for males). The maturation of the sexual products and their emissions requires relatively high energy expenditure, and by consequence the reduction of fish weight during spawning period (Fig. 8)

Size at First Maturity

The analysis of the proportions of the mature horse mackerels (genus *Trachurus*) shows that no individual, whatever his sex, is mature with a size lower than 105 mm, as all the individuals observed are mature with a size total higher (TL) than 225 mm. Length at first maturity was estimated as 155 mm for males and 148.5 mm for females (Fig. 10).

DISCUSSION

During the study period, sex-ratio is slightly in favor of the males, the evolution of this index does not have a phrenological regularity the fluctuations of the sex-ratio. The difficulty in interpreting the fluctuations of this ratio are due to several factors such as the behavior of the species, spawning period and mortality, sampling procedure, and aggregation of the of the same sex individuals. During the period of peak spawning, males outnumber females. This is probably due to a behavioural difference between the sexes (Polonsky & Tormosova, 1969).

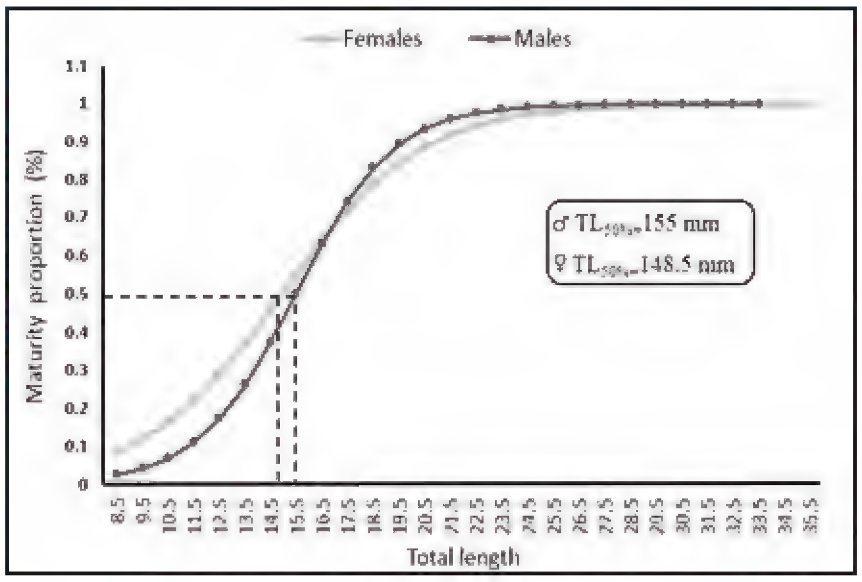

Figure 10. Ogive of sexual maturity of males and females of *Trachurus* of Béni-Saf Bay.

The sexual cycle and spawning period of *Trachurus* fish in the Atlantic coasts have been the subject of several studies (Table 1). In fact, Arruda (1984) noted that the reproduction period of this fish extends from the beginning of November to May on the west Portuguese coasts and also between April and December in Matosinhos Bay. On the other hand, Arruda (1984) showed that *Trachurus* living in the Portuguese coast (Southern coast) spawns throughout the year. Studies on the reproduction of *Trachurus* carried out in the East and the Center-East of the Atlantic showed that the period of the reproduction of this species is not synchronous while passing from one region to another. In contrast, at the North Sea and English Channel coasts, Macer (1974) has shown that the spawning period of *Trachurus* fish is very prolonged during the year and takes place from March to August, while it is shorter in west of the British Isles and takes place from March to June according to Eaton (1989), and from February to May according to Abaunza et al (1995) in North-west of Spain Galician and Cantabrian shelf. Despite the difference in the timing of prematurity, maturation and sexual rest, the spawning period of *Trachurus* in the North-west Atlantic (Abaunza et al., 2003) coincides with that of Present study in Béni-Saf Bay (February-June).

In the Mediterranean coasts, the spawning period varies between 4 and 6 months. Šantić et al (2008) noted the reproduction period of this fish starting from December to May on the Italian east coasts (Adriatic Sea).

In addition, according to Karlou & Economidis (1997) on the coast of Greece, *Trachurus* fish reproduce between December and April. Studies car-

References	**Study area**		**Spawning period**	**TL$_{50\%}$ (cm)**
Letaconnoux, 1951	Golf of Gascogne			19 (shore) 23 (offshore)
Andreu & Rodriguez-Roda, 1951	(NW Mediterranean Sea) Catalonia			15.5
Lozano Cabo, 1952	N/NW coast of Spain			21.1
Planas & Vives, 1953	(NW Mediterranean Sea) Catalonia			16
Gail, 1954	North Africa			15
Barraca, 1964	Portugal			19
Polonsky, 1969	North Sea and English Channel			20–24
Sahrhage, 1970	North Sea			18–19
Sedletskaya, 1971	North Africa			16–23
Macer, 1974	North Sea and English Channel		March to August	20–24
Arneri, 1983	Adriatic Sea			15 - 18
Alegria, 1984	Adriatic Sea			16
Kerstan, 1984	NE Atlantic (British water)			24.2-24.6
Arruda, 1984	Portuguese coast	Western coast	November to May	16 - 19 M 21 – 24 F
		Matosinhos Bay	April to December	
		Southern coast	Whole year	
Kerstan,1985	British & Celtic Sea			24.2-24.6
Korichi,1988	Bousmail bay Algeria			-
Kerstan,1995	Southwest coast of Irland			19.8 M - 25 F
	Northern Biscay			19.4 M - 24.6 F
	South of Biscay			19 M - 25.3 F
Eaton,1989	W British Isles		March to July	
Lucio & Martin,1989	South of Bay Biscay			
Hecht,1990	South-eastern coast of South Africa		June to November	
Borges & Gordo, 1991	Portuguese Coast			22.5
Abaunza et al., 1995	North-western of Spain Galician and Cantabrian Shelf		February to May	20.9 M 21.9 F
Karlou-Riga & Economidis, 1996	Aegean Sea			22
Karlou-Riga and Economidis, 1997	Saronikos Gulf (Greece)		December to April	
Viette et *al*., 1997	Italy-Gulf of Trieste		May to August	15.6 M 16 F
Abaunza et *al*., 2003	North-western Atlantic		February to August	16-25
Šantić et *al*., 2008	E Adriatic Sea		December to May	
Tahari, 2011	Oran Bay (Algeria)		October to March	
Aydin & Karadurmuş, 2012	Ordu Black Sea (Turkey)		May to August	

Table 1/1. Spawning period and length at first maturity obtained by various authors for *Trachurus*.

References	Study area		Spawning period	TL$_{50\%}$ (cm)
Carbonara et *al.*, 2012	Central-western Mediterranean Sea			**GSA 10** 17.8 M 18.9 F **GSA 18** 17.8 M 18.9 F **GSA 19** 17.8 M 18.9 F
Gherram et *al.*, 2018	Oran Bay (Algeria)		January to May	18.42 M 18.28 F
Aydin & Erdoğan, 2018	Northern Aegean Sea (Turkey)		April to August	13 F
Azzouz et *al.*, 2019	Gulf of Skikda (Algeria)		December-April	14 M - 13.65 F
Ferreri et *al.*, 2019	Central Mediterranean Sea	Strait of Sicily		16.1
		Tyrrhenian Sea		17.6
Present study	Béni-Saf Bay		January to July	15.5 cm M 14.85 cm F

Table 1/2. Spawning period and length at first maturity obtained by various authors for *Trachurus trachurus*.

ried out on the west-southern coast of the Mediterranean Sea showed that the spawning period of this species is not regular when moving from one region to another. According to Tahari (2011), in Oran Bay the *Trachurus* fish reproduce between October and March. And in a clear difference, Gherram et al (2018) have shown the *Trachurus* fish living in the same area (Oran Bay) spawning between January to May. On the other hand, according to Azzouz et al. (2019), this fish reproduces between December and April in Skikda Bay.

Our study in Béni-Saf Bay indicates that the spawning period of *Trachurus* is the longest during the year and the monthly evolution of GSI follows a similar pattern for the two sexes. The spawning starts at the beginning of January and continues until June. On the contrary, it is shorter (from May to August) in northern Italy (according to Veet et al., 1997) and also in the Black Sea in Turkey (according to Aydin & Karadurmuş, 2012).

Our study shows that *Trachurus* females reached their sexual maturity at 148.5 mm, earlier than males which attain this maturity at 155 mm. The comparison of our results and those obtained in other geographical areas (Table 1) showed that *Trachurus* of Béni-Saf Bay reaches sexual maturity at earlier size than other regions (Table 1), which makes it possible to think that the fish changed its sexual strategy by maturing earlier in order to ensure its sustainability which is in accordance with Korichi (1988) in central Algerian waters and Gherram et al. (2018) in Oran Bay. In central Mediterranean basin (Adriatic Sea), this length seems to be attained lately between 15 and 18 cm (Arneri, 1983; Alegria-Hernandez, 1984), while in Atlantic Ocean this length is more importantly (Table 1) comprised between 19 and 33 cm (Letaconnoux, 1951; Kerstan, 1985, 1995a, b).

CONCLUSIONS

Through this study, we tried to understand the reproductive behavior of mackerel in the Gulf of Béni Saf.

The results of our study on the reproduction of *Trachurus* of Béni-Saf Bay enable us to supplement the work already made on this species in the Mediterranean Sea allowing a better management of the exploitable resource. Our findings can be a useful tool for scientists, administrators and professionals of the fisheries sector to regulate fishing establishment and update of minimum landing sizes of captures of these species. In addition, there remain many points to be elucidated concerning the fisheries of this species in the Mediterranean basin and Algerian waters especially and which can be the subject of future research.

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First record from the Italian coasts of the overlooked chiton *Acanthochitona pilosa* Schmidt-Petersen, Schwabe et Haszprunar, 2015 (Mollusca Polyplacophora Acanthochitonidae)

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ABSTRACT Within a general overview of the malacological samples deposited in the collection of the Benthic Ecology Laboratory of Messina, numerous specimens of the recently described *Acanthochitona pilosa* Schmidt-Petersen, Schwabe et Haszprunar, 2015 (Mollusca Polyplacophora Acanthochitonidae) were found. The new material, together with further specimens of private collections and literature data allowed a better definition of the *A. pilosa* distributional pattern and some autoecological and biogeographic considerations.

KEY WORDS Mollusc; Mediterranean; Polyplacophora; Biogeography; *Acanthochitona*.

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INTRODUCTION

Four species belonging to the genus *Acanthochitona* Gray, 1821 have been reported to date from the Mediterranean Sea: *A. crinita* (Pennant, 1777), *A. fascicularis* (Linnaeus, 1767), *A. oblonga* Leloup, 1981 and *A. pilosa* Schmidt-Petersen, Schwabe et Haszprunar, 2015 (Kaas, 1985; Dell'Angelo & Smriglio, 1999; Bonfitto et al., 2011).

The most recently described species *A. pilosa*, based on specimens collected in Banyuls sur Mer, south France (Schmidt-Petersen et al., 2015), has been later reported from the Algerian port of Oran and from the Spanish Mediterranean coasts (Amati & Oliverio, 2019).

This species, apparently similar to the congeners *A. crinita* and *A. fascicularis*, may be easily recognized by the peculiar morphology of the aesthetes, which also bear microscopic specific characters. It is therefore surprising that a so peculiar species has remained unknown until nowadays, as well as subsequent reports remained scattered and localized.

In this paper, the finding of numerous specimens collected in different Italian sites is reported, as a contribution to the better understand intraspecific morphological variability, of this overlooked species, further than Mediterranean distribution and habitat.

MATERIALS AND METHODS

All specimens utilized for the present study were collected in two different geographical areas along the Italian coasts (Fig. 1). The most relevant lot is constituted by living specimens hand-collected on lava cliff of eastern Sicily, between August 1980 and September 2019. A second less abundant lot was collected on 2006 in the north-western Tyrrhenian, along the rocky coast of Tuscany.

Both the lots were obtained by scraping hard substratum, which was subsequently picked up under a stereoscope. For morphological studies, specimens were measured, the shape and sculpture of valves were studied and a photographic documentation was provided. Some specimens have been disarticulated to better compare the apophyses and the jugal sinus of some valves and photographed under the binocular microscope to put in evidence shape and size of macro and micraesthetes (Figs. 2–14).

A morphological comparison between three most similar congeneric Mediterranean species has been also carried out (Figs. 2–4).

ACRONYMS AND ABBREVIATIONS. BEL: Benthic Ecology Laboratory, University of Messina, Italy. DSC: Danilo Scuderi Collection (Catania, Italy); WRC: Walter Renda collection (Amantea, Cosenza, Italy).

RESULTS

Systematics

Classis POLYPLACOPHORA Gray, 1821
Subclassis NEOLORICATA Bergenhayn, 1955
Ordo CHITONIDA Thiele, 1909
Superfamilia CRYPTOPLACOIDEA H. Adams & A. Adams, 1858
Familia ACANTHOCHITONIDAE Pilsbry, 1893
Subfamilia ACANTHOCHITONINAE Pilsbry, 1893
Genus ACANTHOCHITONA Gray, 1821
Type-species: *Chiton fascicularis* Linnaeus, 1767 (by monotypy)

Acanthochitona pilosa Schmidt-Petersen, Schwabe et Haszprunar, 2015 - Figs. 2, 5–8, 9–11, 13
Acanthochitona pilosa Schmidt-Petersen et al., 2015: 12

TYPE LOCALITY. France, Banyuls sur Mer (42°28’57” N - 03°08’13” E).

EXAMINED MATERIAL. Italy. Eastern Sicily, Catania, up to 150 specimens collected in December 2002 during BEL sampling campaign (repository code: BEL143FRINGE2002Ap1-140) in the subtidal fringe of lava cliff stretch, -0.1 and -0.2 m, comprised between 37°34’19”N, 15°10’51”E and 37°29’9”N, 15°6’1”E, northern side of Catania, collected by handily scraping hard substrate (see Cosentino & Giacobbe, 2015).

Italy. Eastern Sicily, Catania, 21 specimens from

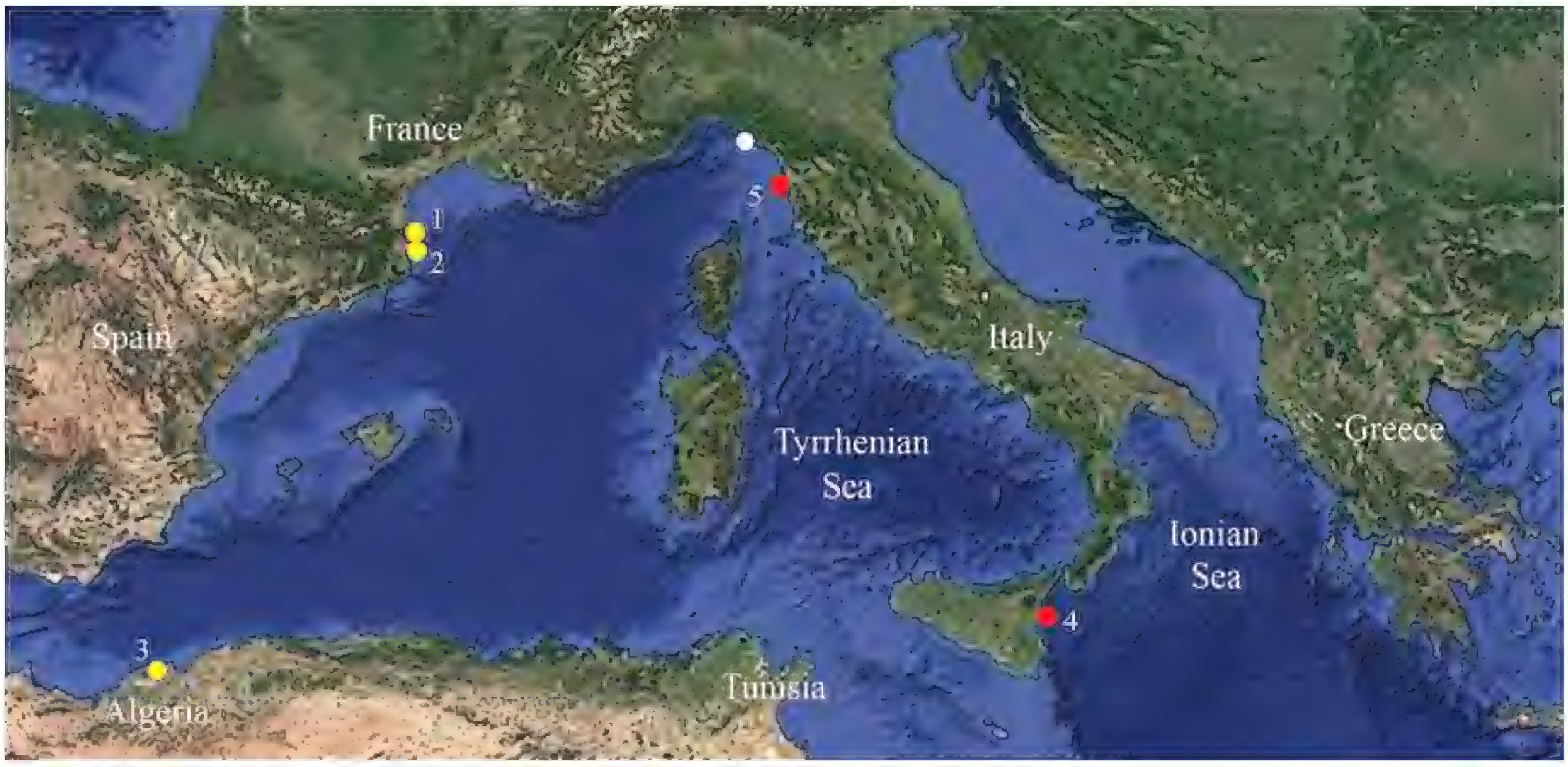
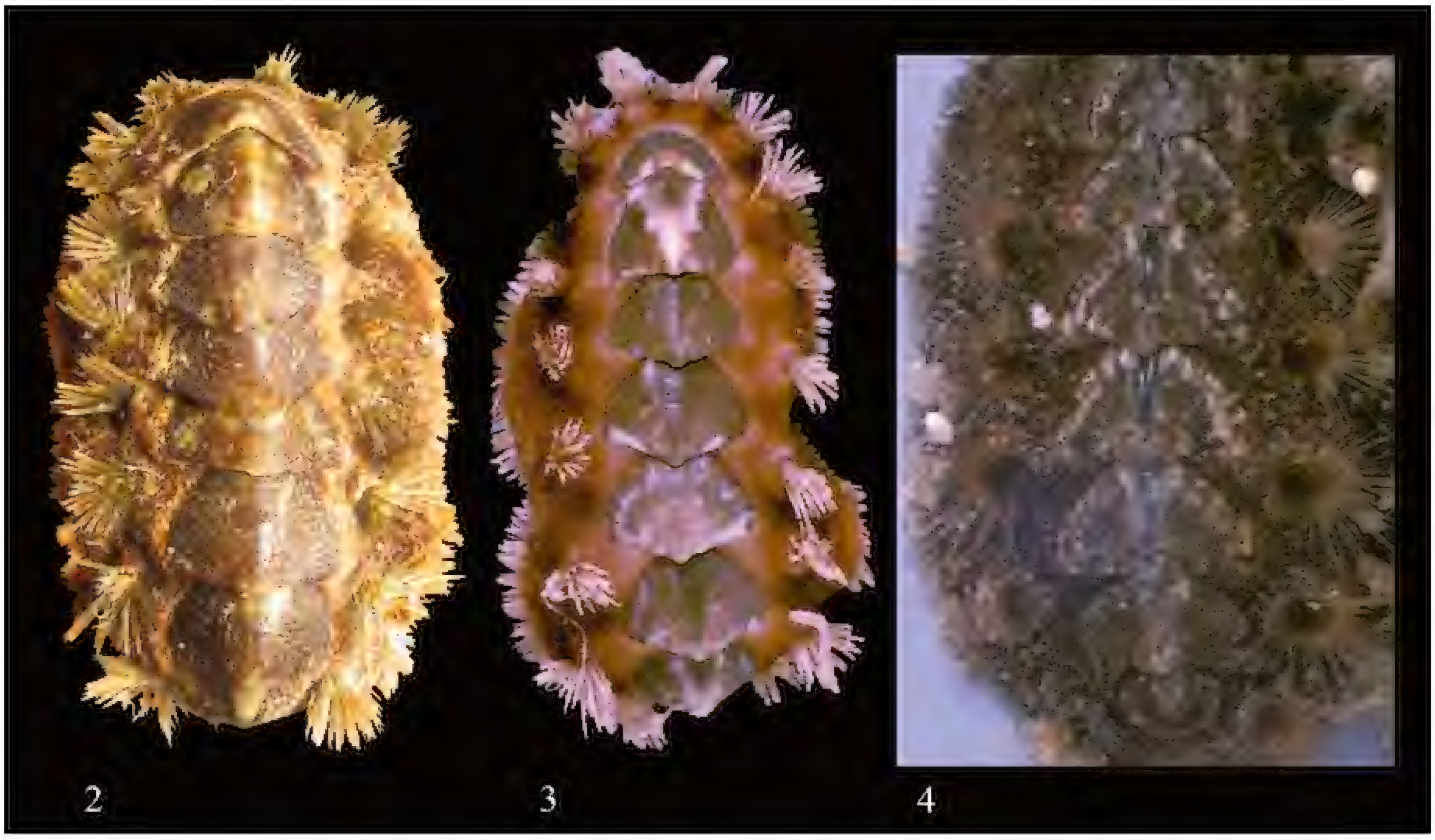


Figure 1. Sampling localities of *Acanthochitona pilosa*. Yellow circles are from literature: 1. Banyuls sur Mer (Schmidt-Petersen et al., 2015); 2. Cadaqués (Amati & Oliverio, 2019); 3. port of Oran (Amati & Oliverio, 2019). Red circles from the present study: 4. Coast of Catania. 5. Calambrone, Tuscany. White circle for unverified records: Riomaggiore (Schmidt-Petersen et al., 2015 in Dell’Angelo & Smriglio, 1999).



Figures 2–4. Comparison between *Acanthochitona pilosa* from Catania (Italy), 14.6 mm (Fig. 2), *A. crinita* from Messina (Italy), 10 mm (Fig. 3), and *A. fascicularis* from Messina (Italy), 11 mm (Fig. 4).

DSC collected from summer 1980 and summer 2019 at San Giovanni Li Cuti, Catania, eastern Sicily (37°31'14"N, 15°06'48"E), intertidal trottoir of vermetids and coralline algae and 10 specimens from WRC collected in December 2002 in Northern side of Catania, collected by handily scraping hard substrate.

Italy, Tuscan coast, Calambrone (Pisa), 43°34'53"N, 10°17'27"E, 3 specimens collected in 2006, by scraping hard substratum in intertidal fringe.

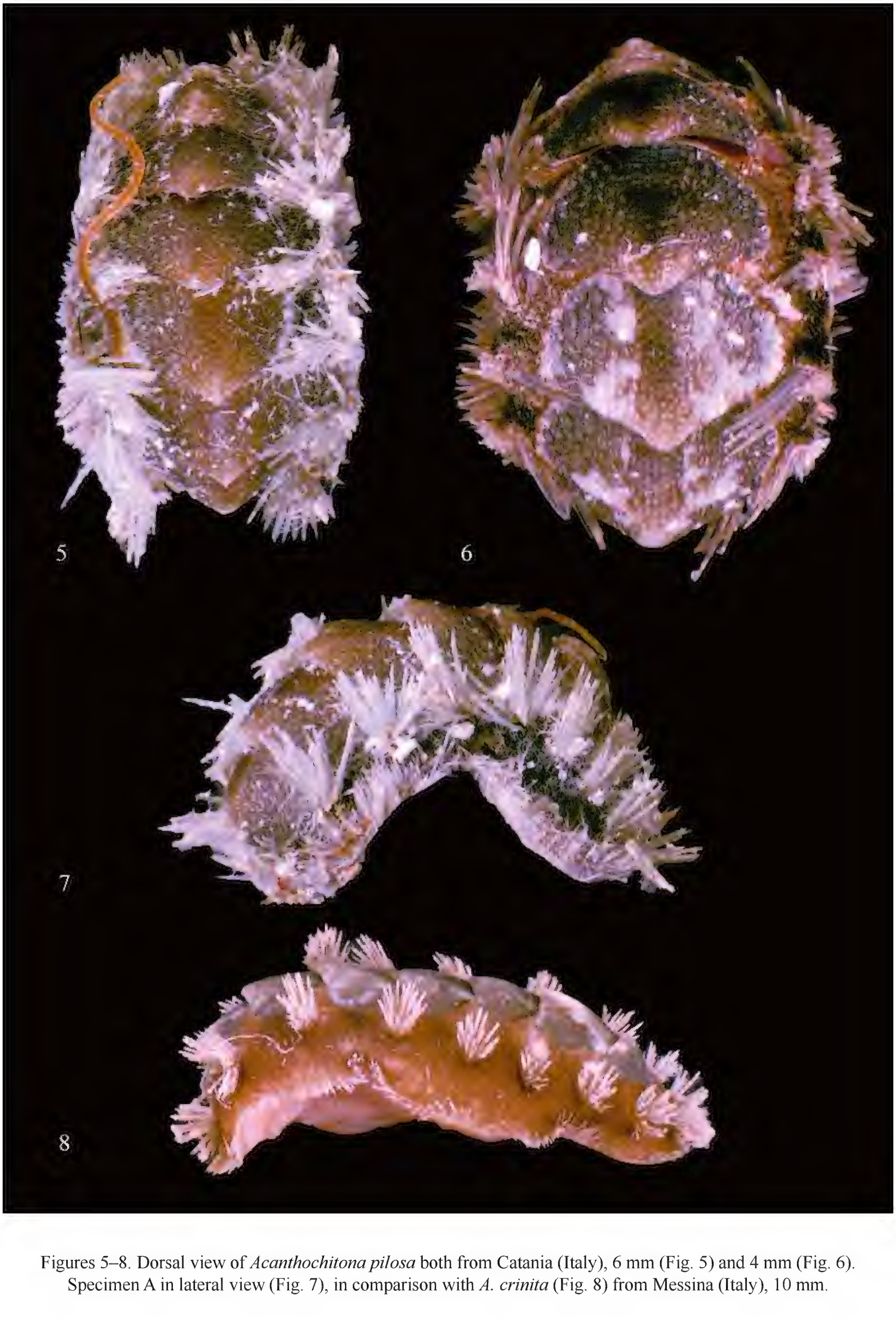
DISCUSSION

The remarkable number of specimens available for the present investigation includes both juveniles and adults, ranging in size from 1 mm to 16 mm in specimens from Sicily and reaching a maximum length of 23 mm in specimens from Tuscany.

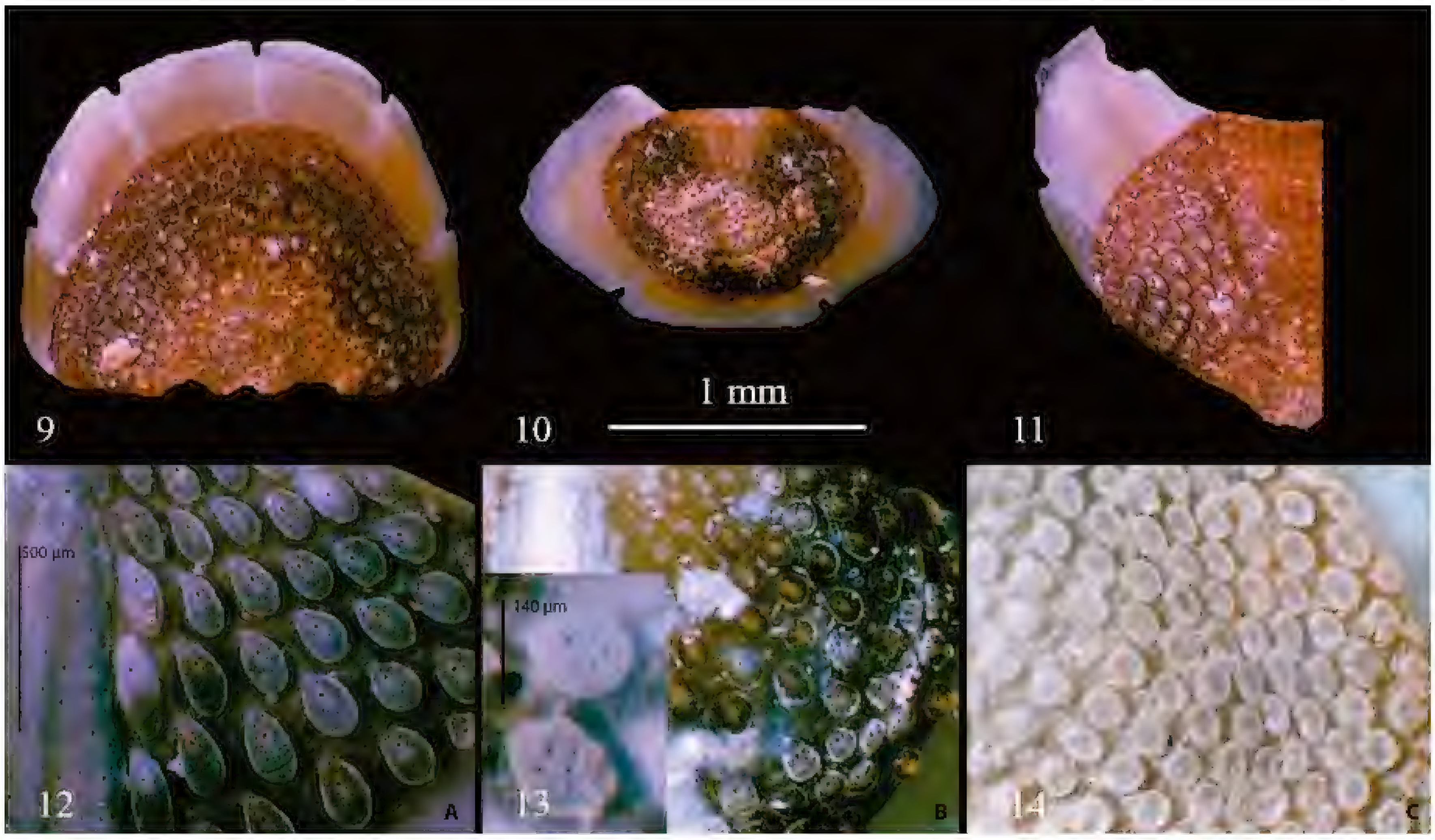
Such material allowed a wider examination of morphological features and diagnostic characters of *A. pilosa*, in comparison with the most similar Mediterranean species, *A. crinita* and *A. fascicularis* (Figs. 2–4). In particular, the peculiar perinotum is here shown in lateral view, in comparison with that of the allied *A. crinita* (Fig. 3–8).

The studied specimens have been all collected in very shallow environments (less than 1 m depth) ranging from the intertidal zone to the sublittoral fringe. The specimens from Sicily, found in the subtidal fringe of lava cliff nearby Catania, have been collected in a rough hard substrates, characterized by crustose red algae covering. In some cases, the specimens have been recorded inside a biogenic intertidal/subtidal ledge formed by encrusting calcareous algae, mussels, *Mytilaster minimus* (Poli, 1795) and *M. galloprovincialis* (Lamarck, 1819), and vermetid gastropods, *Dendropoma cristatum* (Biondi, 1859) and *Vermetus triquetrus* Bivona, 1832. Less data are available for the Tuscan records, which however were found in intertidal hard substrate.

Such new data on the *A. pilosa* habitat agree with early information given by Schmidt-Petersen et al., 2015, which indicated formations of the coralline red alga *Lithophyllum tortuosum* (Esper) Foslie, 1900 as peculiar environment ("trottoir") claimed by the ecological niche of this species. Nevertheless, according to us a sufficiently rough substratum with red-algae covering in the same hy-



Figures 5–8. Dorsal view of *Acanthochitona pilosa* both from Catania (Italy), 6 mm (Fig. 5) and 4 mm (Fig. 6). Specimen A in lateral view (Fig. 7), in comparison with *A. crinita* (Fig. 8) from Messina (Italy), 10 mm.



Figures 9–11. *Acanthochitona pilosa,* dorsal view of head valve (Fig. 9), dorsal view of tail valve (Fig. 10), dorsal view of a median valve (Fig. 11). Figures 12-14. Aesthetes of *A. crinita* (Fig. 12) (specimen of figure 3), *A. pilosa* (Fig. 13) (specimen of figure 2), *A. fascicularis* (Fig. 14) (specimen of figure 4). Micraesthetes of *A. pilosa* are also shown (detail inside figure 13).

drological conditions might simulate the structural characteristic of the intertidal coralline formations, allowing the spread and settlement of *A. pilosa* specimens, in agreement with Schmidt-Petersen et al. (2015), who underline how from literature no typical invertebrate species of the "trottoir" is known. Such Authors, noting that "*these encrustations are commonly found at the Northern coast of the Western Mediterranean*", de facto suggested the areal of *A. pilosa* might be linked to the *Lithophyllum tortuosum* distribution. In this respect, a confirmation was provided by records from Catania, whilst the Oran record of Amati & Oliverio (2019) seems rather to indicate a not exclusive link of the species with algae, since found as epibiontic on a shallow subtidal species which, according to Bouzaza & Mezali (2019), prefers rough, wave exposed substrates.

The present data confirm the occurrence of *A. pilosa* in Italian waters and contribute to enlarge the known areal of *A. pilosa*, which Schmidt-Petersen et al. (2015) hypothesized to be restricted to the Western Mediterranean Basin. The Tuscan record, in fact, together with the unverified Ligurian record of Schmidt-Petersen et al. (2015) agrees with a suggested distributional range "*at least through the Ligurian Sea*". Finally, the Catania records, inside the western Mediterranean biogeographical boundary (Bianchi & Morri, 2000), perfectly agree with the presumed western distributional range.

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Endemism in Italian Orthoptera

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ABSTRACT The present paper discusses about the distribution of orthopterans endemic to Italy. This country is located in the centre of the Mediterranean Basin and its palaeo-geographical origins are owed to complex natural phenomena, as well as to a multitude of centres-of-origin, where colonization of fauna and flora concerned. Out of 382 Orthoptera taxa (i.e., species and subspecies) known to occur in Italy, 160 (41.9%) are endemic. Most of them are restricted to the Alps, the Apennines or the two principal islands of Italy (i.e., Sardinia and Sicily). In addition, lowland areas in central-southern Italy host many endemic taxa, which probably originate from the Balkan Peninsula. In Italy, the following 8 genera are considered endemic: *Sardoplatycleis*, *Acroneuroptila*, *Italopodisma*, *Epipodisma*, *Nadigella*, *Pseudoprumna*, *Chorthopodisma* and *Italohippus*. Moreover, the subgenus *Italoptila* is endemic to Italy. For research regarding endemism, Orthoptera are particularly interesting because this order comprises species characterized by different ecological traits; e.g., different dispersal abilities, contrasting thermal requirements or specific demands on their habitats. The highest percentage of apterous or micropterous (35.3%) and brachypterous (16.2%) endemic taxa live in the Apennines, which are among the most isolated mountains of the Italian Peninsula. Finally, some endemic species are endangered at the European scale.

KEY WORDS Endemic taxa; insularity; isolation; islands; peninsula; mountains; Italy; Alps; Apennines.

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INTRODUCTION

In Europe, the degree of endemism in Orthoptera is generally high (68.3% according to Hochkirch et al., 2016). In Italy, according to the most recent contributions to the Italian Orthoptera (Massa et al., 2012; Baroni et al., 2018), overall 160 of 382 (i.e, 41.9%) taxa are endemic. The origin of these taxa may be mainly due to ancient geographic isolation, which occurred at different stages during earth's history. As a consequence, novel species may have evolved from separated sub-populations which were isolated from other populations for a long time period. High mountains (Alps, Apennines and other isolated areas of high elevation) as well as islands have thus frequently contributed considerably to the evolution of endemic species among Italian Orthoptera. The geodynamic development and rapid paleo-biological changes occurring in the Oligocene played an important role in the evolution of endemic taxa (Steininger & Wessely, 2000). In the early Pliocene, the Mediterranean region was dominated by arid and semi-arid habitats (Suc et al., 1995). These conditions have likely contributed to the evolution of endemic taxa adapted to arid conditions (Verdú & Galante, 2002). During the Pleistocene, thermophilous and psychrophilous species were able to survive in different parts of the Mediterranean in disjunct populations that underwent genetic isolation (Vargas et al., 1998; Baquero & Telleria, 2001; Battisti, 2014). In the Quaternary, the southern Mediterranean peninsulas included hotspots of species richness and endemism. Sea level oscillations and glaciations have been suggested as the main factors of many range disjunctions in Italian butterflies (Racheli & Zilli, 1985). Northern Orthoptera species that remained in isolated populations in southern Italy during the last glacial period (approxiamtely 18,000 years ago) are now recognized as glacial relicts (e.g., *Gomphocerus sibiricus*, which in Italy, currently occurs only in the Alps and Apennines, but which is widespread in the Palaearctic).

The Italian Peninsula is characterized by unique physiographic conditions, which includes the presence of high mountains (Apennines) along the main North-South orientation of the peninsula. The unique shape of the Italian peninsula has been the subject of biogeographical interest by different authors, especially concerning the North-South gradient of impoverishment (e.g., Massa, 1982; Battisti 2006, 2014). The Italian peninsula has two distinct southern tips, in Apulia and in Calabria, respectively, each with very different landscapes (mainly lowlands in Apulia and mountain systems in Calabria). This heterogeneity has probably contributed to the increase of taxonomical diversity in the area. Orthoptera are interesting model organisms as this order includes species with very different dispersal abilities, due to differences in wing development, contrasting habitat preferences, thermophily (Marini et al., 2008). Concerning wing length, many taxa among Italian Orthoptera are wingless, micropterous or brachypterous (158 among the endemic taxa) and this may have increased the degree of geographic isolation during their evolution.

Italy is located in the centre of the Mediterranean Basin and its palaeo-geographical origins are owed to complex natural phenomena, as well as to the close proximity to a multitude of centres-of-origin, where colonization of fauna and flora concerned. Moreover, the Mediterranean Sea in the east and west of the Italian Peninsula represents a natural barrier for Orthoptera species, which may have limited species' dispersal. Italian Orthoptera can be classified by their frequency and range size: (i) abundant and widespread all over the country (e.g., *Tettigonia viridissima* or *Anacridium aegyptium*); (ii) scattered occurrence in particular habitats, but not differentiated compared to other European populations (e.g., *Gomphocerus sibiricus* or *Chorthippus pullus*); (iii) endemic species, which are restricted to particular areas of Italy (e.g., *Decticus loudoni* or *Italopodisma samnitica*). Some of the endemic taxa are represented by allopatric populations, which have been classified as species or subspecies, characterized by one of the following conditions: (i) a unique geographic range or habitat, (ii) a group of phylogenetically concordant arrays of phenotypic and genetic characters, (iii) a unique natural history but low genetic divergence (cf. O'Brien & Mayr, 1991). The absence of gene flow in these allopatric populations have increased genetic differences to other related species. Especially, gene-flow between island and continental populations is strongly reduced (e.g., Fontana & Odé, 1999; Allegrucci et al., 2013). Consequently, we expect that they diverge genetically at a faster rate than continental populations. The same applies to isolated populations on mountain tops (e.g., Fontana & La Greca, 1999b).

In the present paper, we present a review of endemic Italian orthopterans (see also Massa et al., 2001).

MATERIAL AND METHODS

According to Minelli (1974) and Anderson (1994), endemism describes a taxon whose distribution is limited to a geographically confined territory, often small and localized. Thus, a species (or other taxon) is endemic to a biogeographic region if it only occurs in that area. Neverthelesss, these areas may differ in size.

The present paper is based on the Italian Orthoptera database which has formerly been used to publish some monographs on Italian Orthoptera (Kleukers et al., 1997; Fontana et al., 1999, 2016; Fontana & Massa, 2000; La Greca et al., 2000; Massa et al., 2001, 2012; Massa & Fontana, 2011; Iorio et al., 2019) and to contribute to the Red List of European Orthoptera (Hochkirch et al., 2016). Species and genera that are exclusively alpine but do occur also outside Italy were also included in our study. Appendix 1 lists all the Italian Orthoptera, including information on endemism and European threat status (Hochkirch et al., 2016). Italy has not carried out a Red List of Orthoptera, thus information on the staus of Italian Orthoptera is drawn from the Red List of European Orthoptera (Hochkirch et al., 2016). Nomenclature follows the Orthoptera Species File (Cigliano et al., online). For practical reasons, the Italian territory was divided into five biogeographic regions: (i) Alps southwards to the Po Valley; (ii) Apennines; (iii) the Italian Peninsula south from the Po Valley (Apennines excluded) (iv) Sardinia and (v) Sicily (small circum-Sicilian islands included) (Figs. 1-3). For each of these areas the Index of Endemism (EI) was calculated as follows:

Index of endemism (EI) = Number of endemic taxa/Total number of Italian taxa X 100

The same index has been calculated for each biogeographic region by dividing by the total number of regionally occurring taxa of the concerned area.

RESULTS AND DISCUSSION

Out of 382 Orthoptera taxa (i.e., species and subspecies) known to occur in Italy, 160 (41.9%) are endemic (Fig. 4). The total number of species found in the biogerographic regions of Italy is reported in the Table 1.

Endemism on the islands of Sicily and Sardinia

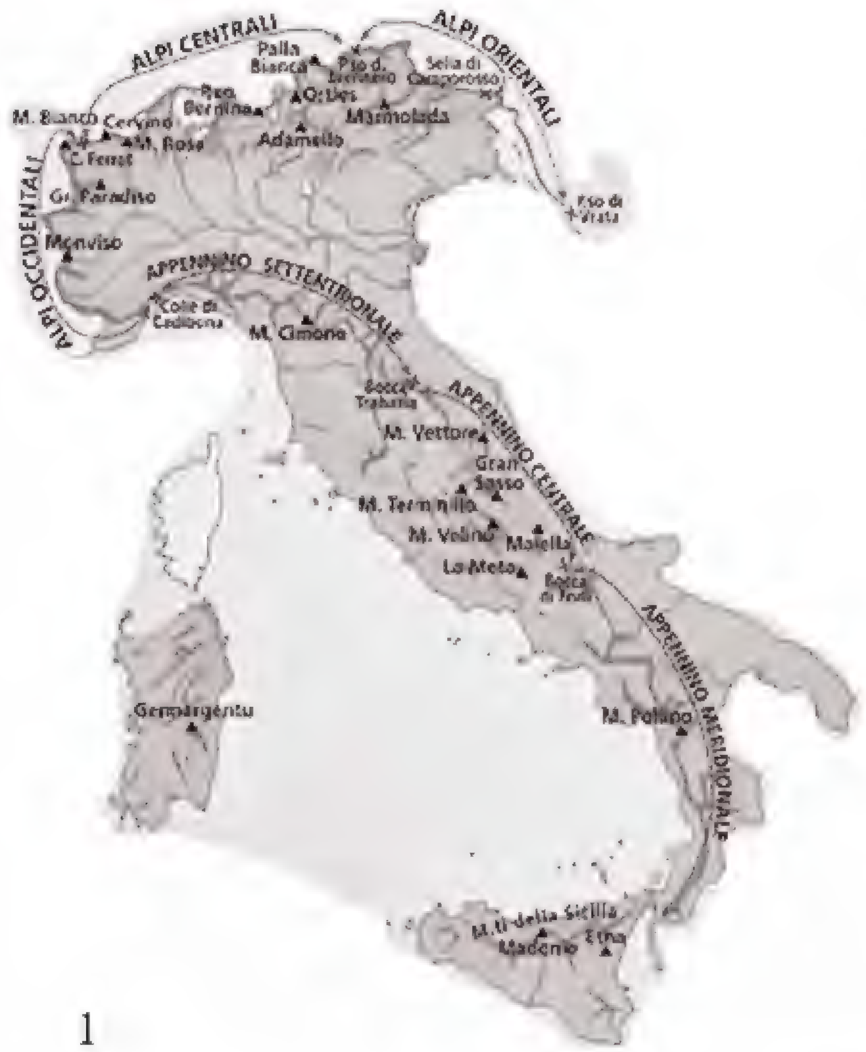
[Sicilian taxa here considered: *Leptophyes sicula*, *Odontura arcuata*, *Platycleis concii*, *Platycleis ragusai*, *Tessellana lagrecai*, *Incertana drepanensis*, *Eupholidoptera bimucronata*, *Ctenodecticus siculus*, *Ephippiger camillae*, *Uromenus bonneti painoi*, *Uromenus brevicollis trinacriae*, *Uromenus riggioi*, *Uromenus siculus*, *Gryllotalpa cossyrensis* (Pantelleria Is.), *Pamphagus marmoratus*, *Pamphagus ortolanii* (Lampedusa Is.), *Acinipe galvagnii*, *Ochrilidia sicula*, *Dociostaurus minutus*, *Omocestus lopadusae* (Lampedusa Is.), *Chorthippus brunneus raggei*, *Chorthippus messinai*, *Chorthippus trinacriae*, *Euchorthippus albolineatus siculus*]

[Sardinian taxa here considered: *Odontura calaritana*, *Tettigonia longispina*, *Sardoplatycleis galvagnii*, *Rhacocleis baccettii*, *Rhacocleis corsicana*, *Rhacocleis maculipedes*, *Ctenodecticus bolivari bolivari*, *Uromenus annae*, *Uromenus brevicollis insularis*, *Dolichopoda muceddai*, *Acroneuroptila puddui*, *Acroneuroptila sardoa*, *Gryllotalpa vigintiunum*, *Pamphagus sardeus*, *Oedipoda caerulescens sardeti*, *Oedipoda fuscocincta morini*, *Sphingonotus candidus candidus*, *Sphingonotus uvarovi*, *Ochrilidia nuragica*, *Euchorthippus sardous*]

In spite of only small differences in their area (Sardinia: 24,090 km^2, Sicily: 25,709 km^2), the two islands differ substantially in their total number of Orthoptera species (98 and 127 species, respectively) recorded up to now. This may be due to both the higher degree of geographical isolation of Sardinia as well as the lower level of knowledge of orthopterofauna in this region. In total, 25 taxa are endemic to Sicily, whereas among the Sardinian orthopterans 19 taxa are endemic (EI: see Table 1). These data confirm the importance of Mediterranean islands as hotspots of biodiversity (Médail & Quézel, 1999).

It is difficult to evaluate if the presence of species endemic to these islands is relictual or due to passive dispersal, such as human introduction. For example, *Metaplastes pulchripennis*, present in many regions of Italy and neighbouring countries, has been also found in the Nebrodi Mountains on Sicily. Since there is no morphological difference between Sicilian and peninsular populations of this species, it is hard to assess whether its presence on the island represents an ancient relict population of mainland provenance or a more recently established population. Genetic analyses might help to gain more knowledge on this issue. Similarly, it is difficult to answer whether *Metaplastes ippolitoi*, described by La Greca (1949) from Calabria and recently found in the Madonie Mountains on Sicily by Fontana et al. (2004), was accidentally introduced to Sicily or whether its presence on this island reflects a formerly wider distribution.

Until 2010, *Leptophyes sicula* which is endemic to Siciliy, was prreviously considered as a population of the widespread European species *L. punctatissima*. The micropterous genus *Leptophyes* includes many morphologically similar species that can be distinguished by their stridulatory songs (Kleukers et al., 2010). *Eupholidoptera bimucronata* (morphologically related to the Italian *E. magnifica*), two species of *Platycleis* (*P. ragusai* and *P. concii*), *Tessellana lagrecai* (morphologically related to, if not conspecific with, *T. tessellata*, widespread in Eurasia and North Africa), *Ephippiger camillae* (known only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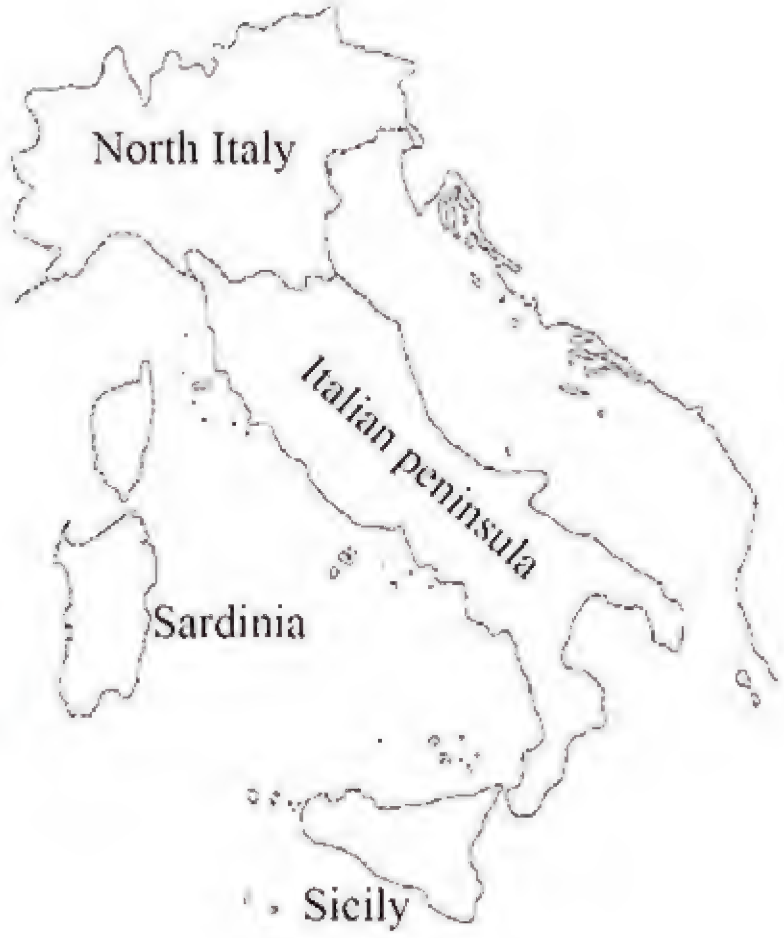
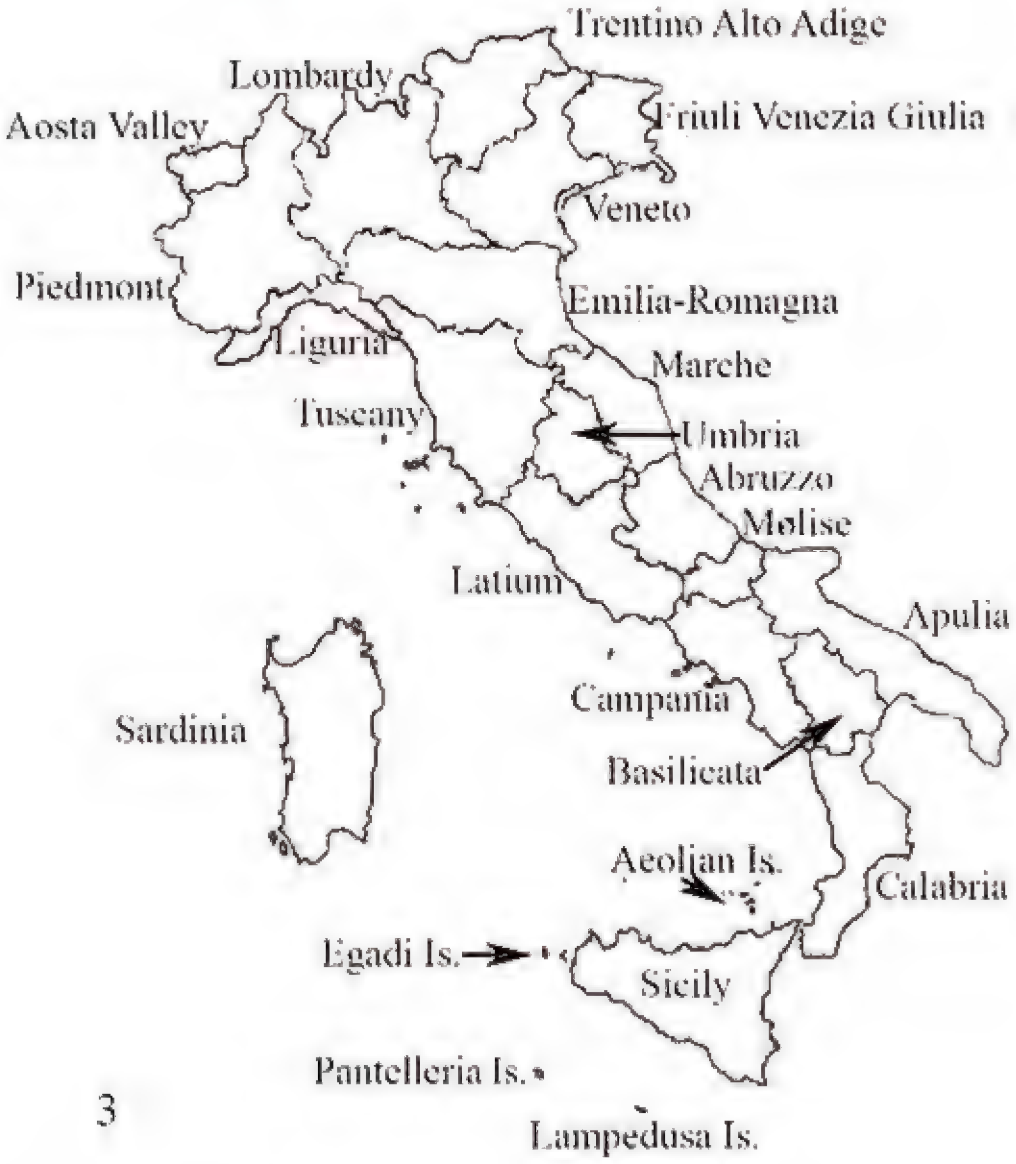
ALPI ORIENTALI
ALPI OCCIDENTALI
Palla Bianca
Pso d. Brennero
Sella di Campo
Rco. Bernina
Ortles
Marmolada
M. Bianco
Cervino
M. Rosa
C. Ferret
Adamello
Gr. Paradiso
Pso di Vrata
Monviso
APPENNINO SETTENTRIONALE
Colle di Cadibona
M. Cimone
Bocca Trabaria
APPENNINO CENTRALE
M. Vettore
Gran Sasso
M. Terminillo
M. Velino
Maiella
La Meta
Bocca di Forli
APPENNINO MERIDIONALE
Gennargentu
M. Pollino
M.ti della Sicilia
Madonie
Etna

1


North Italy
Italian peninsula
Sardinia
Sicily

2


Trentino Alto Adige
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Friuli Venezia Giulia
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Piedmont
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Liguria
Marche
Tuscany
Umbria
Abruzzo
Molise
Latium
Apulia
Campania
Sardinia
Basilicata
Aeolian Is.
Calabria
Egadi Is.
Sicily
Pantelleria Is.
Lampedusa Is.

3

Figure 1. Physical map of Italy, showing Alps, northern, central, and southern Apennines, and the islands of Sicily and Sardinia. Figure 2. Boundaries of northern Italy (from Alps to Po Valley), Italian Peninsula, Sardinia, and Sicily. Figure 3. Map of Italy showing all the regions.

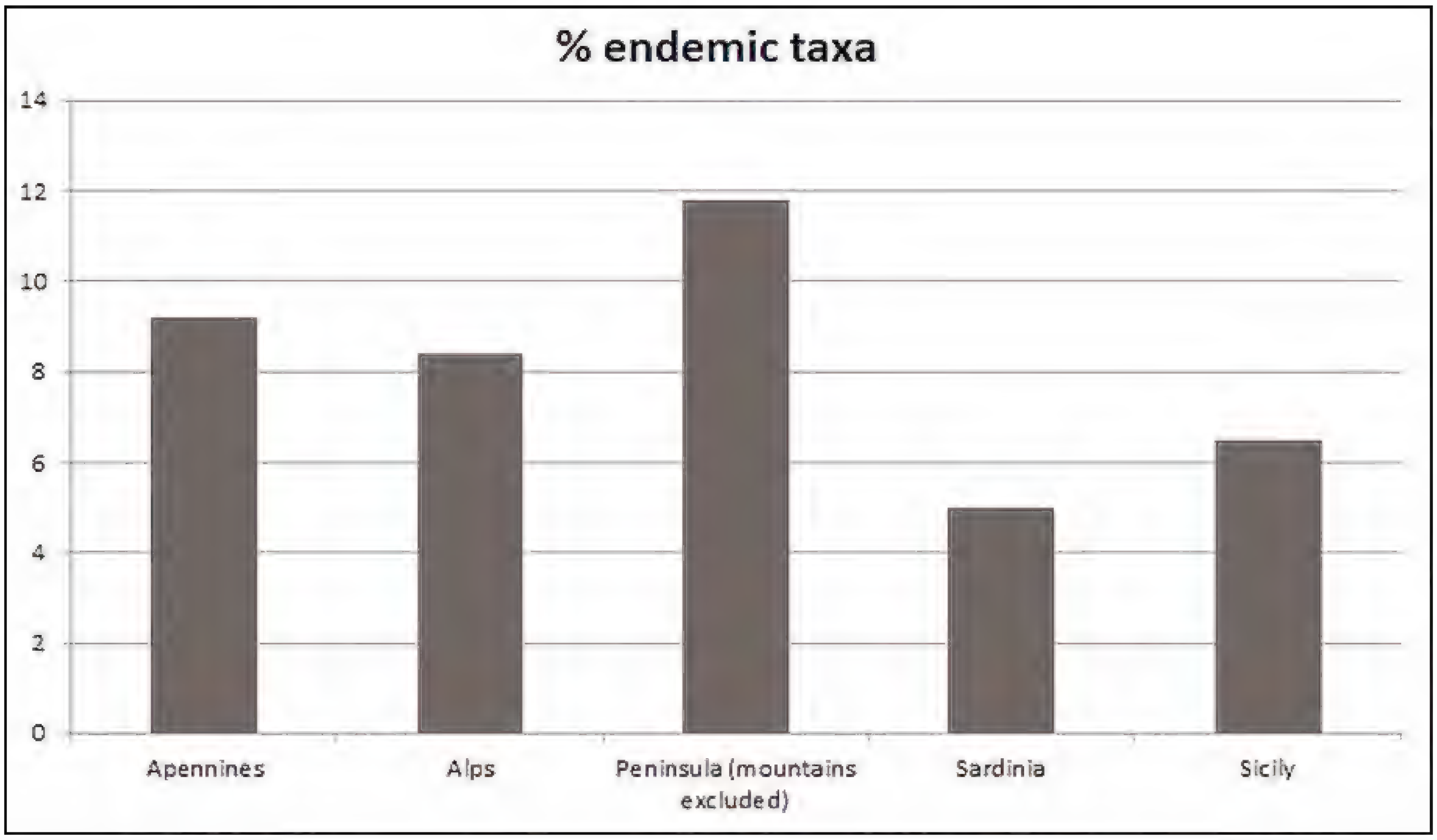


Figure 4. Percentage of endemic species of Orthoptera in different areas of Italy.

	Alps	Apennines	Peninsular Italy (Apennines excluded)	Sicily	Sardinia
Ensifera	56	40	108	72	55
Caelifera	52	28	80	55	43
Total	108	68	188	127	98
EI of Italian orthopterofauna	8.4%	9.2%	11.8%	6.5%	5.0%
EI of orthopterofauna of concerned areas	29.6%	51.5%	23.9%	19.7%	19.4%
Apterous or Micropterous taxa	21 (19.2%)	24 (35.3%)	33 (17.5%)	13 (10.2%)	10 (10.2%)
Brachypterous taxa	13 (11.9%)	11 (16.2%)	7 (3.7%)	7 (5.5%)	1 (1.0%)
Long-winged taxa	0	0	5 (2.6%)	5 (3.9%)	8 (8.2%)

Table 1. Total number of taxa in the Alps, Apennines, Peninsular Italy, Sicily and Sardinia; percentage of endemic Orthoptera calculated with the Index of Endemism (see methods) on the whole Italian orthopterofauna and in the concerned areas; number of apterous or micropterous, brachypterous and long-winged taxa within the endemic taxa in the concerned areas (in parenthesis the percentage on the total number of taxa known from the area). Source: Massa et al. (2012), Iorio et al. (2019).

from the holotype, collected in the Madonie Mountains), *Uromenus siculus* (morphologically related to *U. elegans* from Italy and the Balkan peninsula), and three taxa of the genus *Chorthippus* (*C. brunneus raggei*, *C. messinai*, *C. trinacriae*) may be considered as allopatric subpopulations, maintained by spatial segregation as a result of vicariance events during recent earth's history.

The genus *Odontura*, which has a Western Mediterranean distribution, including the Iberian peninsula and North Africa (Warchalowska-Sliwa et al., 2011; Grzywacz et al., 2013), is present in both Sicily and Sardinia with two endemic species: *Odontura arcuata* (which can be distinguished from *Odontura stenoxypha,* occurring in Sicily and North Africa, only chromosomally, cf. Messina, 1981) and *Odotura calaritana*. According to Grzywacz et al., (2013), *O. arcuata* should be considered as a subspecies of *O. stenoxypha*, but the populations of both species do probably overlap.

Other species with similar distributional patterns are: *Tettigonia longispina* from Sardinia, morphologically related to the Maghrebian *T. savignyi*; *Uromenus annae* from Sardinia, related to the North African species *U. bouiblani* (Nadig, 1995) from north Morocco, *U. i. innocentii* (Bonnet & Finot, 1885) from Morocco, Algeria, and Tunisia, and *U. m. moulouyae* (Nadig, 1995) from Morocco (Buzzetti et al., 2019); *Pamphagus sardeus*, related to the Tunisian *P. tunetanus* Vosseler, 1902 and to *P. ortolanii* from the island of Lampedusa (that was physically connected to Tunisia up to at least 16,000 years ago); *P. marmoratus*, a Sicilian endemic morphologically related to western Maghrebian species distributed in Algeria and Morocco [e.g. *P. elephas* (L., 1758) and *P. caprai* Massa, 1992]; *Pterolepis elymica* from Sicily, related to *Pterolepis pedata* from Sardinia, Lampedusa and Tunisia; *Ctenodecticus b. bolivari* from Sardinia (*C. b. africanus* Galvagni, 1990 lives in Tunisia); *C. siculus* from Sicily; *Ochrilidia sicula* from Sicily and *O. nuragica* from Sardinia [both morphologically related to the Afro-Asian *O. geniculata* (Bolívar, 1913)]; *Uromenus brevicollis trinacriae* from Sicily and *U. brevicollis insularis* from Sardinia, both morphologically similar to the north African *U. b. brevicollis* (Fischer, 1853).

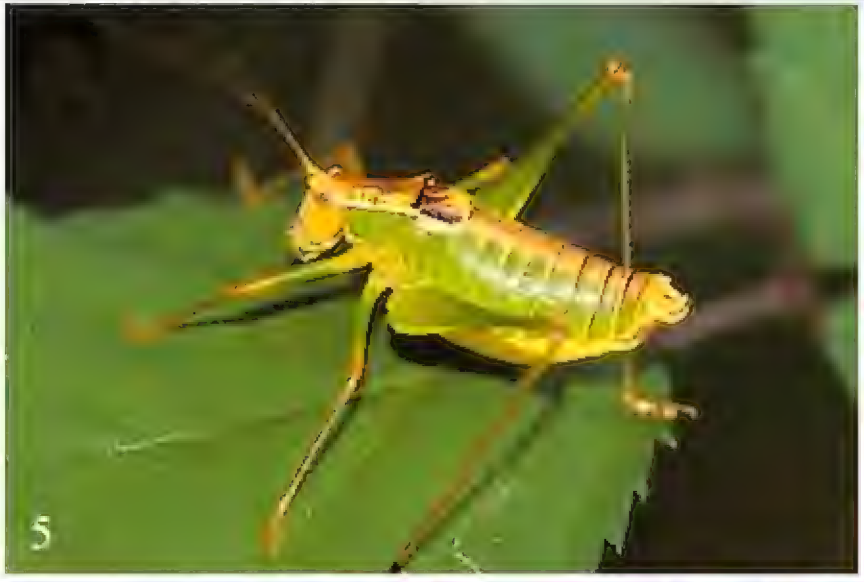
Incertana drepanensis from Sicily is the sole Italian representative of a genus widespread from the Middle East to North Africa and the Iberian Peninsula; *Acinipe galvagnii* from Sicily is related to *A. hesperica* Rambur, 1838, a North African and Iberian species. Another species of *Acinipe*, *A. calabra*, is distributed in Calabria, Sicily, and North Africa. *Uromenus bonneti* is present in Tunisia, on the island of Lampedusa (*U. b. bonneti*) and in Sicily (*Uromenus bonneti painoi*). *Dociostaurus minutus* from Sicily and *Omocestus lopadusae* from Lampedusa are related to the North African brachypterous species *Dociostaurus dantini* Bolívar, 1914 and *Omocestus fontanai* Massa, 2004. Furthermore, *Euchorthippus albolineatus siculus* is endemic to Sicily, while the typical form (*E. a. albolineatus*) is distributed in North Africa. By contrast, it is difficult to find morphological relations between *Uromenus riggioi* and any Maghrebian species.

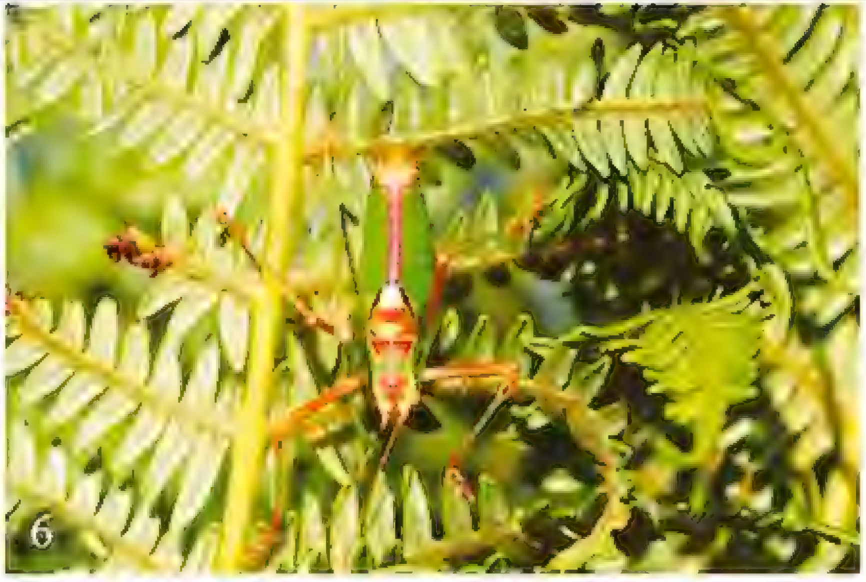
Interestingly, Sardinia, which is more isolated than Sicily, holds some endemic taxa with no clear morphological similarities to other European (including Corsica island) and African taxa: *Sardoplatycleis galvagnii* (endemic genus), *Rhacocleis baccettii*, *R. maculipedes*, *Acroneuroptila puddui*, *Acroneuroptila sardoa*, *Sphingonotus uvarovi*, and the brachypterous species *Euchorthippus sardous.*

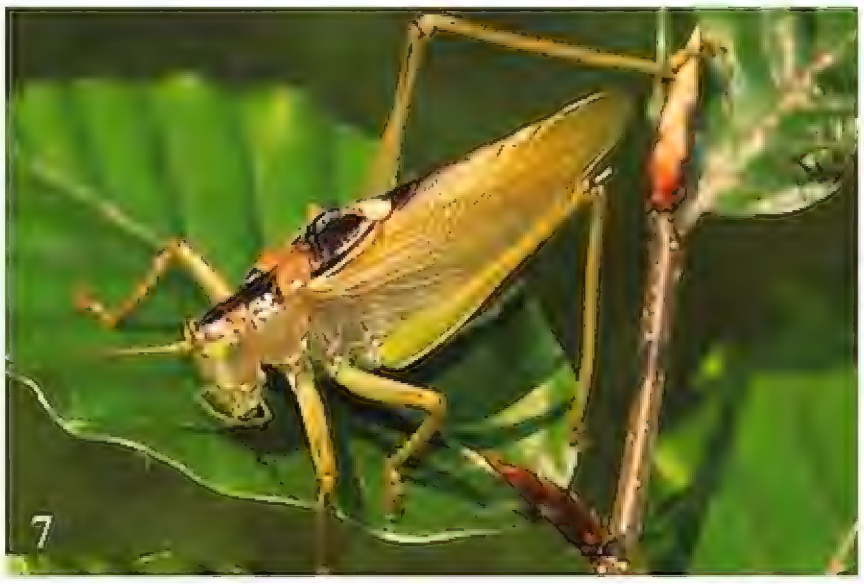
Endemism in the Alps and Apennines

[Italian endemic taxa from Alps here considered, including those present also in Switzerland, Austria and France: *Barbitistes vicetinus*, *Anonconotus pusillus*, *A.alpinus*, *A. baracunensis*, *A. ghilianii*, *A. italoaustriacus*, *A. ligustinus*, *A. occidentalis*, *Chopardius pedestris apuanus*, *Pholidoptera littoralis insubrica*, *Ephippiger persicarius*, *Ephippiger terrestris* spp., *Podisma d. dechambrei*, *Podisma dechambrei melisi*, *Podisma eitschbergeri*, *Podisma pedestris nadigi*, *Podisma pedestris caprai*, *Miramella alpina*, *Nadigella f. formosanta*, *Nadigella formosanta bessae*, *Kisella irena*, *Pseudoprumna baldensis*, *Chortopodisma cobellii*, *Epipodisma pedemontana*, *Odontopodisma decipiens insubrica*, *Pararcyptera alzonai*, *Stenobothrus ursulae*. *Stenobotrhus cotticus*, *Chorthippus cialancensis*, *C. sampeyrensis*, *C. a. alticola*, *C. alticola rammei*, *Chorthippus mollis ignifer*, *Chorthippus saulcyi daimei*]

[Endemic taxa from Apennines here considered: *Tettigonia silana*, *Decticus aprutianus*, *Metrioptera caprai caprai*, *Metrioptera caprai baccettii*, *Metrioptera caprai galvagnii*, *Metrioptera caprai lagrecai*,







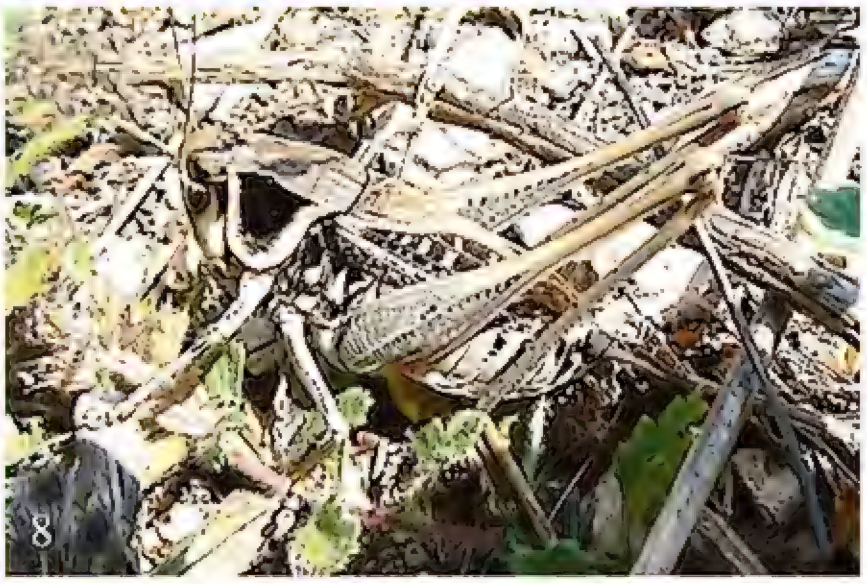


Figure 5. *Metaplastes ippolitoi* (male), endemic to Calabria and Sicily (photo P. Fontana). Figure 6. *Leptophyes sicula* (male), endemic to Sicily (photo T. La Mantia). Figure 7. *Tettigonia silana* (male), endemic to La Sila mountains (Calabria) (photo P. Fontana). Figure 8. *Decticus loudoni* (male), endemic to Apulia (photo B. Massa).

Pholidoptera aptera goidanichi, *Eupholidoptera brunneri*, *Anonconotus apenninigenus*, *Anonconotus sibyllinus*, *Ephippiger carlottae*, *Ephippiger ruffoi*, *Ephippiger melisi*, *Podisma emiliae*, *Podisma goidanichi*, *Podisma magadalenae*, *Podisma ruffoi*, *Podisma silvestrii*, *Italopodisma acuminata acuminata*, *Italopodisma acuminata marsicana*, *Italopodisma baccettii*, *Italopodisma costae*, *Italopodisma ebneri*, *Italopodisma fiscellana*, *Italopodisma lagrecai*, *Italopodisma samnitica*, *Italopodisma trapezoidalis trapezoidalis*, *Italopodisma trapezoidalis aprutiana*, *Italopodisma trapezoidalis curvula*, *Stenobothrus apenninus*, *Italohippus albicornis*, *Italohippus modestus*, *Italohippus monticola*]

High mountains (the Alps, Apennines, and other isolated areas of high elevation) also contribute to the high proportion of endemic species among Italian Orthoptera. In total, the Italian Alps (cf. Figs. 1a, 1b, 1c), harbour 108 species, including 32 endemic taxa (EI: see Table 1). In the Apennines, there are 68 taxa, 35 endemic (EI: see Table 1). The adult phenology of species living at high elevations covers only the period between July and September, with oviposition mainly in August. This short period may explain the remarkable concentration of populations in some places, as well as a noteworthy fluctuation in the density of some species.

The origin of many Alpine and Apennine endemics in Italy is probably the result of Quaternary climatic oscillations, which have led to geographic isolation of species from genera originating from Central Europe in their Italian range, such as *Metrioptera*, *Decticus*, *Podisma*, *Chortopodisma*, *Pseudoprumna*, *Nadigella*, *Stenobothrus* and *Chorthippus*. For instance, Alpine and Apennine species of the genus *Podisma* are well characterized by morphological differences (Fontana & Pozzebon, 2007).

Barbitistes vicetinus, several *Anonconotus* species, *Pseudoprumna baldensis* and *Chortopodisma cobellii* are also endemic to the Alps. The genus *Barbitistes* has a Euro-Asiatic distribution, ranging from the Caucasus to the Iberian Peninsula. *B. vicetinus* is a quite common species, which occurs in a restriced area in north-eastern Italy, yet it was first discovered only in 1993. Furthermore, there are also endemic taxa at generic level (*Epipodisma*, *Chortopodisma*, *Pseudoprumna*, *Italopodisma* and *Italohippus*).

Restricted to the Apennines, the genus *Italohippus* is characterized by minor but regular morphological differences that allow the separation of three species from the genus *Chorthippus* (Fontana & La Greca, 1999a). Furthermore, *C. rubratibialis* is an endemic species, replacing *C. biguttulus* in the Apennines. It occupies all kinds of dry habitats, grasslands, roadside verges, forest clearings, and wasteland. *C. karelini bruttius* (Fontana et La Greca, 1999b), which is distributed in the southern Apennines and is currently considered as a subspecies of a species distributed in central-eastern Europe and Asia, should be considered an old relict taxon deserving of true species status. *Stenobothrus apenninus* is widespread in the northern and central Apennines, with an isolated southern population on Mount Pollino. This species inhabits alpine meadows in elevations between 1000–2300 m a.s.l. Two *Anonconotus* species endemic to the Apennines (*A. apenninigenus* and *A. sybillinus*) are morphologically related to western Alpine taxa, from which they evolved due to geographic isolation during the glacial period. Recurrent glaciations have contributed to a unique mountainous fauna characterized by more widely distributed northern species. In addition, the presence of xerothermic habitats probably favoured the evolution of endemic taxa (Kenyeres et al., 2009).

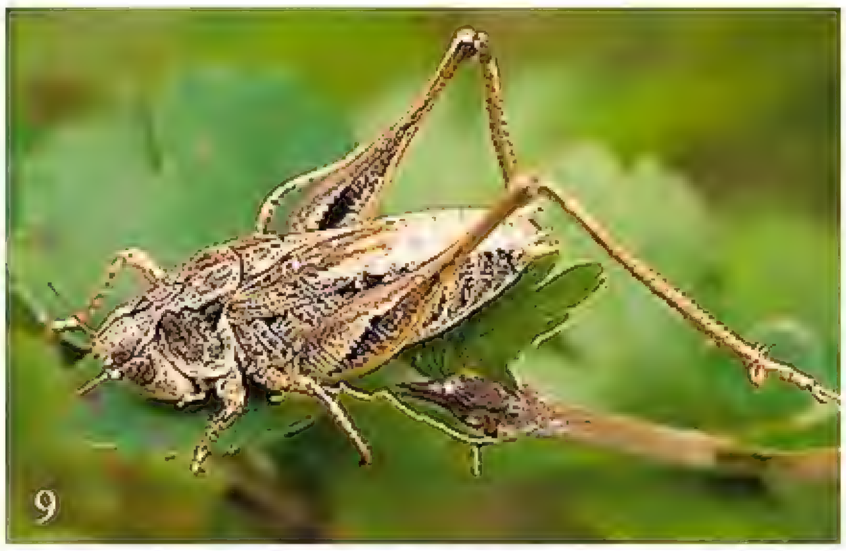
The tribe Podismini, characterized by brachypterism or apterism, occurs in the Alps and Apennines with many endemic taxa. These are sometimes restricted to single mountain tops and probably originated through Quaternary climatic oscillations. The taxonomic status of some species has to be verified (e.g., the taxonomic status of populations currently recognized as subspecies of *Podisma pedestris* and *Italopodisma trapezoidalis* should be revised, as some of these are probably synonymous). However, there is evidence that most of them are endemic taxa. Additionally, uninvestigated high mountain environments could yield further new endemic taxa. Interestingly, the genus *Italopodisma* is related to the Balkan genus *Peripodisma* Willemse, 1972, suggesting a Transjonian origin. The latter genus was described from one species from the Pindos Mountain (Greece), *P. tymphii*. Only recently, Lemonnier-Darcemont & Darcemont (2015a, b) recorded two other species in Albania, *P. ceraunii* Lemonnier-Darcemont et Darcemont, 2015 and *P. llofizii* Lemonnier-Darcemont et Darcemont, 2015.

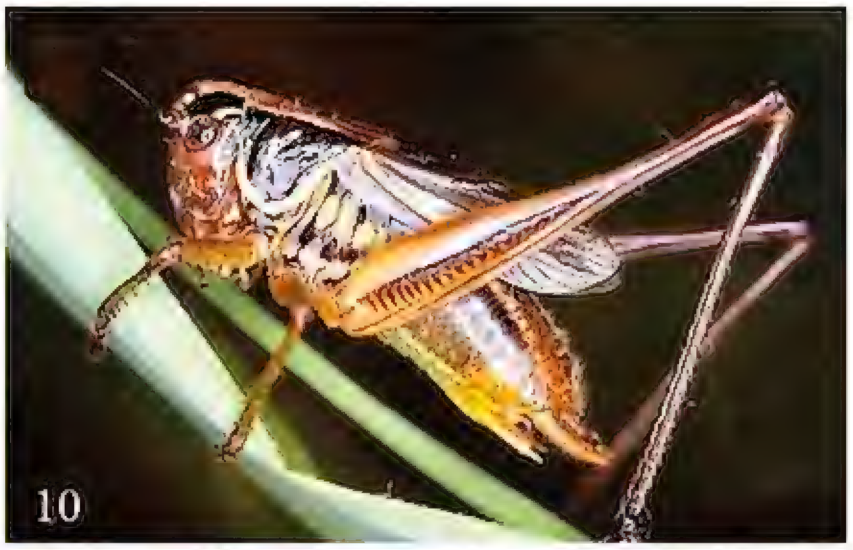
The Apennines also host interesting populations of different species of the genus *Decticus*: *D. aprutianus* is a very short-winged species, distributed in the central Apennines and Calabria (with a differentiated population from a bioacoustic point of view), most probably isolated from populations of *Decticus loudoni* from southern Italy (Apulia). The distribution of *D. verrucivorus* and *D. aprutianus* may overlap but male stridulation is distinctly different. In the central Apennines, there are populations of very short-winged *Decticus* species that are clearly different from *D. aprutianus*, but with stridulatory patterns like those of *D. verrucivorus*. The taxonomic status of this populations requires further research. *Tettigonia silana* is probably related to the Euro-Asiatic *T. cantans*, from which it is separated on the basis of its song (Ragge & Reynolds, 1998; Fontana & Odé, 1999; Heller, 2006; Massa et al., 2012), or even more closely related to *T. balcanica* Chobanov et Lemonnier-Darcemont, 2014. *T. silana* is present in only one area of the Sila Mountains (Calabria) at moderate altitudes.

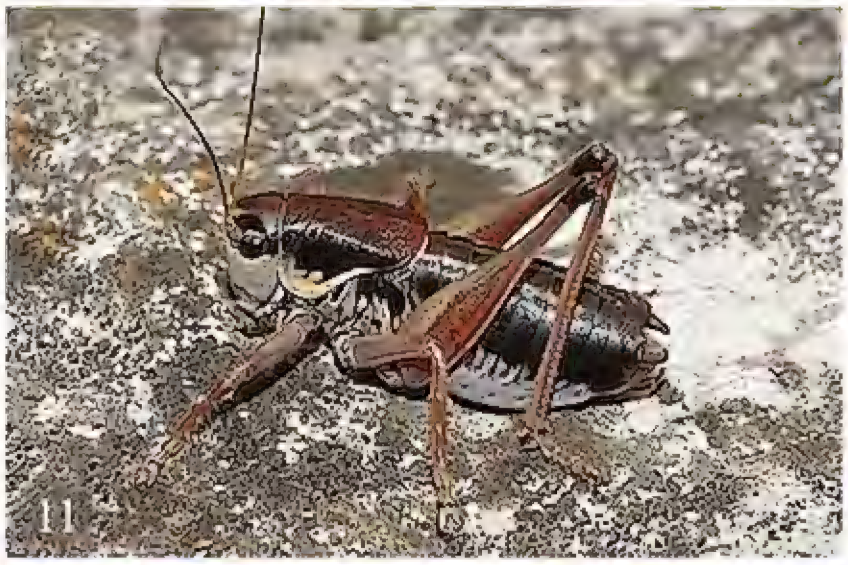
Chrysochraon beybienkoi is an endemic relict species only known from an area near Lake Ampollino (Calabria). Its closest relative is *C. dispar*, which occurs only in north-eastern regions of Italy.

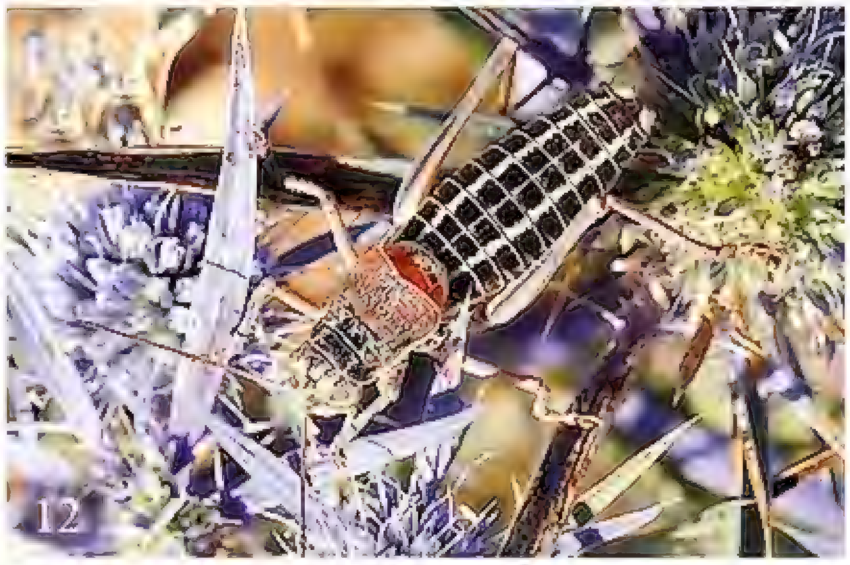
Endemism in the Italian Peninsula (Apennines excluded)

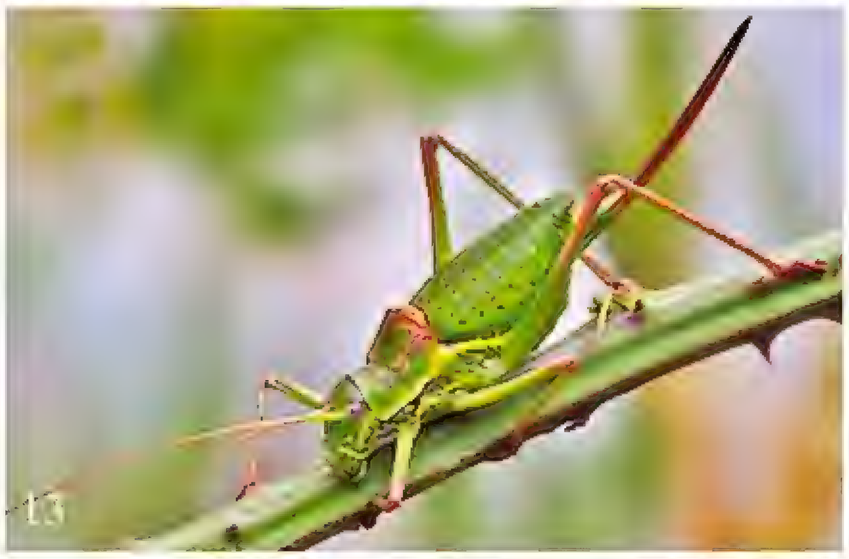
[Endemic taxa from the Italian Peninsula here considered: *Acrometopa italica*, *Poecilimon superbus, Decticus loudoni, Platycleis romana, Tessellana nigrosignata, Roeseliana brunneri, Zeuneriana marmorata, Pholidoptera littoralis insubrica, Eupholidoptera danconai, Eupholidoptera hesperica, Eupholidoptera magnifica, Rhacocleis japygia, Rhacocleis thyrrhenica, Ephippiger apulus apulus, Ephippiger apulus italicus, Ephippiger cavannai, Ephippiger perforatus, Ephippiger zelleri, Dolichopoda aegilion, Dolichopoda azami ligus-*

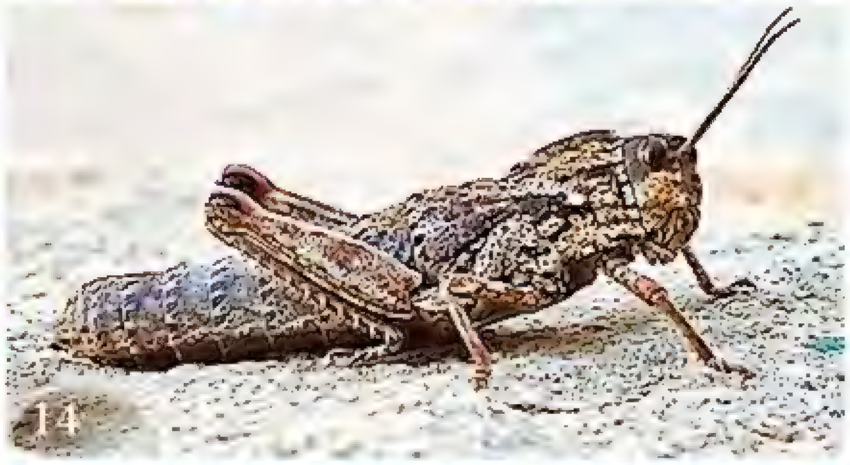


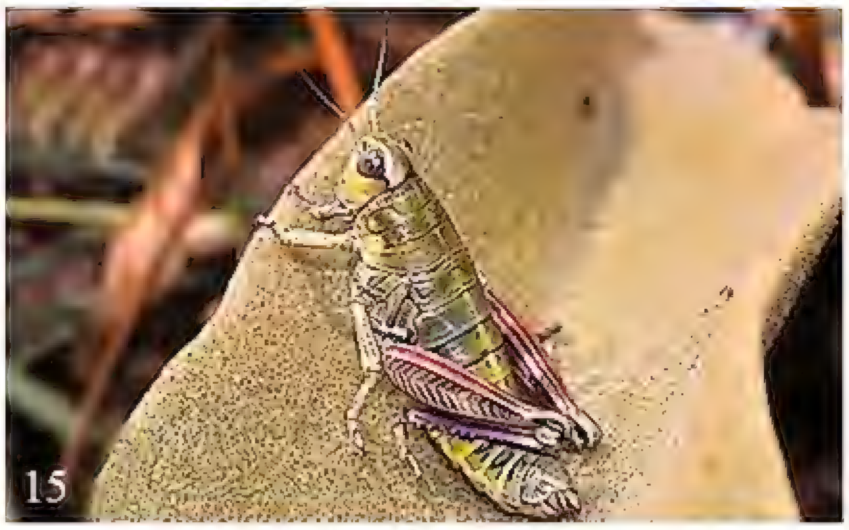












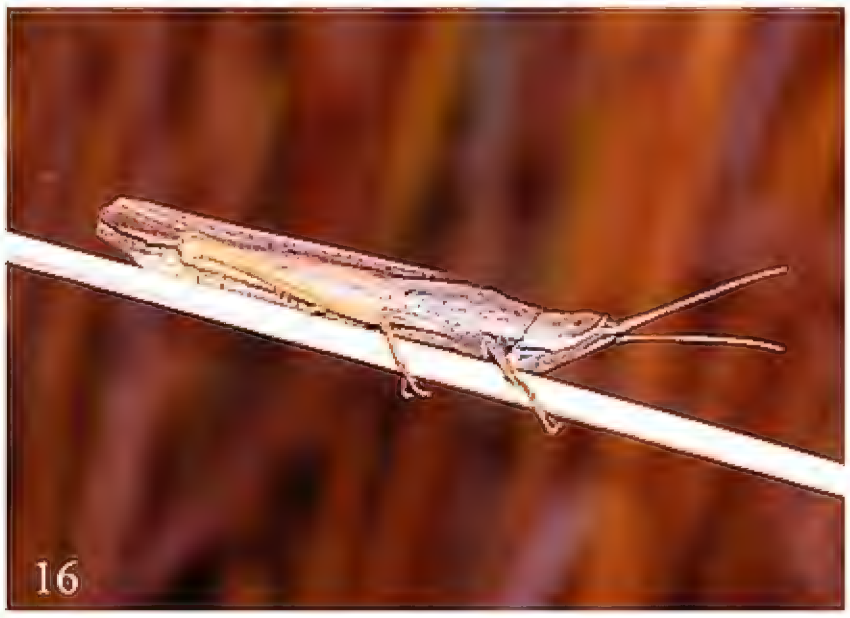


Figure 9. *Platycleis concii* (male), endemic to calcareous areas of western Sicily. Figure 10. *Roeseliana brunneri* (male), endemic to Veneto and Friuli. Figure 11. *Anonconotus sybillinus* (male), endemic to the Apennines. Figure 12. *Ephippiger ruffoi* (male), endemic to the Apennines (Figs. 9-12 photos P. Fontana). Figure 13. *Ephippiger zelleri* (female), endemic to central Italy (photo R. Scherini). Figure 14. *Acinipe galvagnii* (female), endemic to the Egadi islands and western Sicily (photo T. Puma). Figure 15. *Italopodisma costae* (female), endemic to the Apennines (photo P. Fontana). Figure 16. *Ochrilidia sicula* (male), endemic to the sand dunes of Sicily, now in decline and endangered (photo B. Massa).

tica, Dolichopoda azami septentrionalis, Dolichopoda baccettii, Dolichopoda capreensis, Dolichopoda geniculata geniculata, Dolichopoda geniculata pontiana, Dolichopoda laetitiae laetitiae, Dolichopoda laetitiae etrusca, Dolichopoda palpata, Dolichopoda schiavazzii schiavazzii, Dolichopoda schiavazzii caprai, Troglophilus andreinii andreinii, Troglophilus andreinii hydruntinus, Gryllomorpha dalmatina schmidti, Petaloptila andreinii, Petaloptila clauseri, Petaloptila sbordonii, Gryllotalpa octodecim, Gryllotalpa quindecim, Gryllotalpa sedecim, Gryllotalpa viginti, Prionotropis appula, Tropidopola graeca transjonica, Sphingonotus personatus, Omocestus uvarovi, Chorthippus dorsatus garganicus]

At least 45 endemic taxa, within a total number of 188 species, are distributed in non-mountainous areas along the Italian peninsula (EI: see Table 1, cf. also Kleukers et al., 1997; Gomboc & Segula, 2005; Fanin et al., 2016), where they mostly occur in isolated, arid or semi-arid habitats (e.g., the non endemic genera *Acrometopa, Poecilimon, Ephippiger, Eupholidoptera, Rhacocleis, Prionotropis, Oedipoda, Dociostaurus,* and *Chorthippus*).

The genus *Ephippiger* has a Euro-Asiatic distribution from the Caucasus to the Iberian Peninsula (however, one species is also found in Somalia: Baccetti, 1985). The Italian Peninsula holds six endemic taxa of *Ephippiger* (in addition to two endemic Apennine taxa). Consequently, it can be assumed that Italy is an important center of evolutionary radiation for these brachypterous orthopterans, with mating systems based on bioacoustical recognition.

Lowland areas in the Italian peninsula may have represented important refuges during the glacial periods. Examples of endemic taxa that remained isolated during Pleistocene glaciations include *Prionotropis appula*, probably of Transjonian origin, *P. willemsorum* Massa et Ünal, 2015, which is associated with the Balkan region (Massa et al., 2015); *Tropidopola graeca tansjonica*, a subspecies endemic to Apulia (the typical subspecies, *Tropidopola g. graeca* Uvarov, 1926 lives in the Balkan peninsula); *Decticus loudoni* in South-East Italy (Apulia), which probably evolved from the Balkan populations of *D. verrucivorus*; *Oedipoda cynthiae*, an endemic species which is probably related to *O. miniata* and currently only known from Apulia (Fontana et al., 2019).

The genus *Eupholidoptera* has been examined by Allegrucci et al. (2013) who concluded that at least eight endemic taxa occur in Italy. Genetic differences suggest that *E. schmidti*, which occurs in northern Italy, *E. garganica* from Apulia (of Transjonian origin, being also present in Greece), and *Eupholidoptera hesperica*, from southern Italy, are the most differentiated species. By contrast, *E. chabrieri* is the least genetically differentiated (Allegrucci et al., 2013). These results suggest that the Italian *Eupholidoptera* comprise species with a very different history of isolation. The brachypterous genus *Rhacocleis* also shows a high level of endemism, with at least five Italian endemic species; this can be explained by its limited dispersal abilities.

Finally, we would like to include a note on the species-rich genus *Chorthippus*, probably the most diverse genus occurring in the Mediterranean Basin. The species of this genus are morphologically very similar and often only males can be identified morphologically. Willemse et al. (2009) have highlighted the possibility that some species may hybridize. A case of probable transient hybridization has been described for the pre-Alps by Fontana et al. (2002). In Italy, this genus includes 21 species, some of which are morphologically very similar, being however characterized by different song.

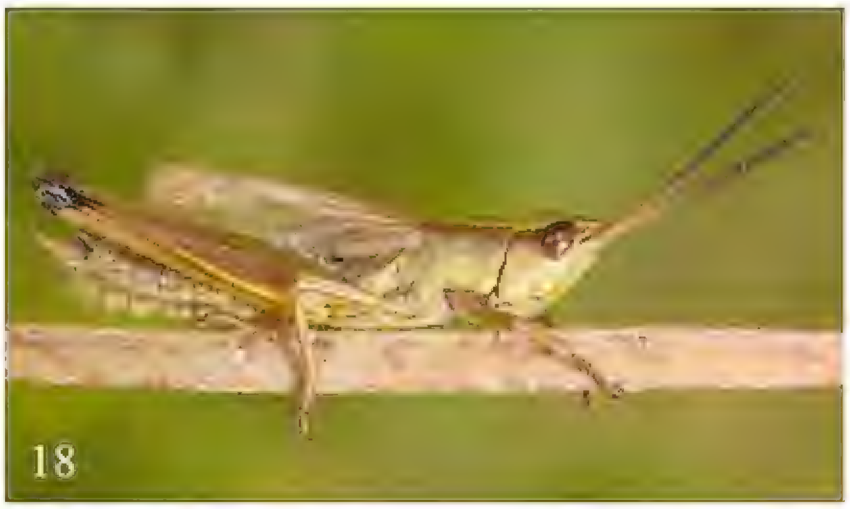
The present climate also depends on the geometry and topography of the Italian peninsula. Climatic differences lead to different environmental conditions, which crucially affect distribution of Italian Orthoptera species. In addition to the strong North-South gradient along the Italian peninsula, Italy is characterized by a strong elevational range. Both contribute to a strong climatic gradient which is responsible for the outstandingly high diversity of flora and fauna. If we exclude the Apennine chain, species richness across the Italian peninsula decreases with increasing elevation. The Italian peninsula is divided into at least two bioclimatic zones: (i) Temperate mid-continental climate (temperate continental/humid continental climate), which includes the Alps, the Po Valley, and the northern part of the Apennines from Liguria to Emilia Romagna; (ii) Mediterranean (temperate with dry, hot summers and mild wet winters), which includes all the area south of the previous zone. Furthermore, the Mediterranean bioclimatic zone is divided into at least two sub-zones: a) Mediterranean-temperate, from the Tuscan-Emilian Apennines to Campania; b) Mediterranean-arid from

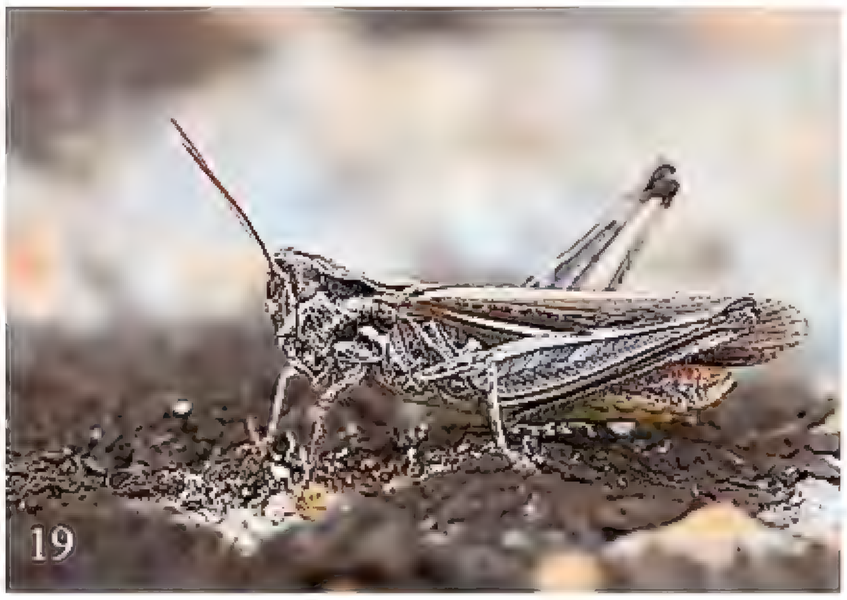
Campania to the southern tips of the peninsula (Pignatti, 1979; Massa, 1982). The latter zone hosts some species typical of arid lands of the Mediterranean that are not found elsewhere in Italy.

CONCLUSIONS

The total number of species in northern Italy and the Italian peninsula is very similar, but the number of Alpine species is higher than that of Apennine species (109 and 68, respectively). This may be due to the decrease in species richness linked to the ‘peninsula effect’ generally observed in animal groups (Massa, 1982; Battisti, 2006), but also to a different territory surface (Alps are connected with continental landmass, while Apennines are represented by an isolated dorsal ridge). The importance of the relation between geographic conditions and endemism occurrence has been already highlighted by Anderson (1994). The situation in the Balkan Mountains is similar to the Italian peninsula. However, the Italian peninsula is surrounded by the Mediterranean sea along its east and west flanks. This strongly limits new colonizations of Orthoptera species. Furthermore, this resulted in a high level of isolation of less mobile species particularly adapted to high elevations. In particular, this applies to *Italopodisma* and other Podismini, as well as some species of the genus *Metrioptera* (the Apennine *M. caprai* may be considered as the ecological substitute of the Alpine *M. saussuriana*), *Ephippiger*, and others.

Many European species reach their southern distribution limit in northern Italy while a few Central-European species have been able to colonize the Italian peninsula with established populations, and adapt to new habitats. As a consequence of geographic isolation, some of them have evolved into new, endemic taxa (e.g., endemic species and genera living in the Apennines).





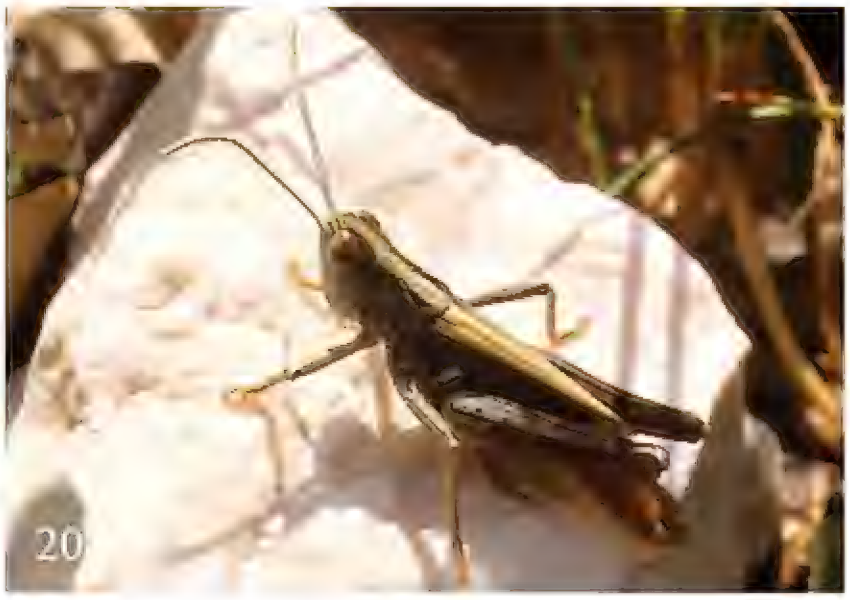


Figure 17. *Dociostaurus minutus* (male), endemic to the sand dunes of South-East Sicily (photo T. Puma). Figure 18. *Chrysochraon beybienkoi* (male), endemic to the Ampollino lake (Calabria) (photo P. Fontana). Figure 19. *Chorthippus rubratibialis* (female), endemic to the Apennines (photo R. Scherini). Figure 20. *Italohippus albicornis* (male), endemic to the Apennines (photo P. Fontana).

Due to their ecological isolation, caves acted as micro-refugial centres, favouring the evolution of endemic taxa in the genera *Troglophilus* (two species in north-eastern Italy and another one in southern Italy: Sbordoni et al., 1981), *Dolichopoda* (12 species on the Italian peninsula, one in Sardinia: Baccetti & Capra, 1959, 1970; Di Russo et al., 1994; Casale et al., 2005) and *Acroneuroptila* (a genus endemic to Sardinia with two species: Baccetti, 1960; Cadeddu, 1970).

The case of Orthoptera is particularly interesting because this insect order comprises species characterized by different ecological traits; e.g., different dispersal abilities, contrasting thermal requirements or specific demands on their habitats characterized by different ecological traits (Table 1). Interestingly, the highest percentage of apterous or micropterous (35.3%) and brachypterous (16.2%) endemic taxa live in the Apennines, the most isolated mountains of the Italian pensinsula. However, a high percentage of apterous or micropterous (17.5%) taxa also occur across the Italian peninsula (Apennines excluded), where they remained isolated at least since the last glacial event (approximately 16-18,000 years ago).

Finally, a millenary human history on the Italian pensinsula historically contributed to an increase in habitat heterogeneity and more recently led to fragmentation of habitats which may have favoured anthropophilous, generalist species. The latter one may cause severe range losses or even extinction among endemic species, due to progressive extinction of stenotopic species. Furthermore, mediterranean lands have been strongly influenced by human activities and thus translocations of species may have occurred during the last centuries. Moreover, there are some species that have high dispersal abilities, which may also be able to expand their ranges. An interesting case of species spreading has been observed during 2016, when a Japanese merchant ship anchored one mile off the coast of Barbate (Andalucia, Spain) between 12th and 25th September was completely invaded by flying *Gryllus bimaculatus*. These crickets, days after when the ship arrived in Malta, were still alive and some of them were observed mating. Lately the ship left Malta and sailed through the Suez Channel directed to Japan (Luigi Pizzo, pers. comm. to BM). It is then possible some of those crickets have been transferred from Spain to Japan. A similar case of passive transport of the much less common *Brachytrupes megacephalus* from Sicily to Malta has been reported by Cassar & Galdies (2018). This allows us to conclude that some species are unsuitable to understand the evolution of regional Orthoptera faunas while endemics, generally consisting of a few small populations, are the well-suited indicators to understand biogeographical patterns.

Considering conservation status of the Italian endemic Orthoptera, out of 136 species included in the European list (subspecies were not considered in the European Red List), 66 are Least Concern, 12 Near Threatened, 16 Vulnerable, 27 Endangered, and 16 Critically Endangered. In total, this accounts for 59 species (43.4%) which may suffer future declines. Among the 29 species endemic to the Apennines included in the European Red List, 6 are Least Concern, 4 Vulnerable, 12 Endangered, and 7 Critically Endangered (Table 2; Appendix 1).

	Least Concern	Near Threatened	Vulnerable	Endangered	Critically Endangered
Tettigoniidae	27	9	6	9	7
Rhaphidophoridae	10		4		
Gryllidae + Gryllotalpidae	4		3		
Pamphagidae	4	2			
Acrididae	21	1	3	18	8
Total (136)	**66 (48.5%)**	**12 (8.8%)**	**16 (11.8%)**	**27 (19.8%)**	**15 (11.0%)**

Table 2. Number and percentage (in parenthesis) of the Italian endemic species included in different categories of conservation concern for each family of Italian Orthoptera. The percentage refers to the total number of Italian endemic species included in the European Red List. Source: Hochkirch et al. (2016).

APPENDIX 1

List of species and subspecies among Italian Orthoptera, their distribution in Italy, and their Red List status. Abbreviations. E = endemic. Red List (according to Hochkirch et al., 2016): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not available. In bold: endemic taxa.

Family/species		Red List	Endemic taxa (E)	Distribution
Tettigonidae				
1	*Phaneroptera falcata* (Poda, 1761)	LC		North and Gargano, Apulia
2	*Phaneroptera nana* Fieber, 1853	LC		Italian peninsula, Sicily, and Sardinia
2	*Tylopsis lilifolia* (Fabricius, 1793)	LC		Italian peninsula, Sicily, and Sardinia
4	***Acrometopa italica* Ramme, 1927**	LC	E	Italian peninsula, Sicily, and Sardinia
5	*Acrometopa macropoda* (Burmeister, 1838)	LC		From Friuli Venezia Giulia to Apulia
6	*Isophya modestior* Brunner, 1882	LC		Friuli, Veneto, Trentino, and Lombardy
7	*Barbitistes alpinus* Fruhstorfer, 1920	LC		Alps and north Apennines
8	*Barbitistes fischeri* (Yersin, 1854)	LC		Parco Naz. Gran Paradiso, Piedmont
9	*Barbitistes ocskayi* Charpentier, 1850	LC		Carso, Friuli Venezia Giulia
10	*Barbitistes serricauda* (Fabricius, 1794)	LC		North-east Italy and north Apennines
11	***Barbitistes vicetinus* Galvagni et Fontana, 1993**	NT	E	Veneto and Trentino
12	*Barbitistes yersini* Brunner, 1878	LC		Friuli Venezia Giulia and Abruzzo
13	***Metaplastes ippolitoi* La Greca, 1948**	LC	E	Calabria and Sicily
14	*Metaplastes pulchripennis* (A. Costa, 1863)	LC		Italian peninsula and Sicily
15	*Andreiniimon nuptialis* (Karny, 1918)	VU		Carso Triestino, Umbria and Marche
16	*Leptophyes albovittata* (Kollar, 1833)	LC		Trentino Alto Adige
17	*Leptophyes boscii* Fieber, 1853	LC		Alps and north Apennines
18	***Leptophyes calabra* Kleukers, Odé et Fontana, 2010**	CR	E	Calabria
19	*Leptophyes laticauda* (Frivaldsky, 1867)	LC		Italian peninsula
20	*Leptophyes punctatissima* (Bosc, 1792)	LC		Italian peninsula and Sardinia
21	***Leptophyes sicula* Kleukers, Odé et Fontana, 2010**	LC	E	Sicily
22	***Odontura arcuata* Messina, 1981**	LC	E	Sicily
23	*Odontura borrei* Bolívar, 1878	LC		Is. of Lampedusa (Sicily)
24	***Odontura calaritana* A. Costa, 1883**	LC	E	Sardinia
25	*Odontura stenoxypha* (Fieber, 1853)	LC		Sicily

26	*Poecilimon elegans* Brunner, 1878	LC		North-east Italy
27	*Poecilimon laevissimus* (Fischer, 1854)	LC		Sicily
28	*Poecilimon ornatus* (Schmidt, 1850)	LC		North-east Italy
29	***Poecilimon superbus* (Fischer, 1854)**	LC	E	Italian peninsula
30	*Poecilimon thoracicus* (Fieber, 1853)	LC		Carso Goriziano (Friuli Venezia Giulia)
31	*Polysarcus denticauda* (Charpentier, 1825)	LC		Alps and central-north Apennines
32	*Meconema meridionale* A. Costa, 1860	LC		Italian peninsula and Sicily
33	*Meconema thalassinum* (De Geer, 1773)	LC		Italian peninsula
34	*Cyrtaspis scutata* (Charpentier, 1825)	LC		Italian peninsula, Sicily, and Sardinia
35	*Conocephalus (Conocephalus) conocephalus* (Linnaeus, 1767)	LC		Italian peninsula, Sicily, and Sardinia
36	*Conocephalus (Anisoptera) d. dorsalis* (Latreille, 1804)	LC		Central-north Italy
37	*Conocephalus (Anisoptera) fuscus* (Fabricius, 1793)	LC		Italian peninsula, Sicily, and Sardinia
38	*Ruspolia nitidula* (Scopoli, 1786)	LC		Italian peninsula, Sicily, and Sardinia
39	*Tettigonia cantans* (Fuessly, 1775)	LC		Italian peninsula and Sardinia
40	*Tettigonia caudata caudata* (Charpentier, 1854)	LC		North-east Italy
41	***Tettigonia longispina* Ingrisch, 1983**	CR	E	Sardinia
42	***Tettigonia silana* Capra, 1936**	DD	E	Calabria
43	*Tettigonia viridissima* (Linnaeus, 1758)	LC		Italian peninsula, Sicily, and Sardinia
44	*Decticus albifrons* (Fabricius, 1775)	LC		Italian peninsula, Sicily, and Sardinia
45	***Decticus aprutianus* Capra, 1936**	LC	E	Apennines
46	***Decticus loudoni* Ramme, 1933**	VU	E	Apulia
47	*Decticus v. verrucivorus* (Linnaeus, 1758)	LC		Central-north Italy, Sardinia?
48	*Platycleis a. affinis* Fieber, 1853	LC		Italian peninsula and Sicily
49	*Platycleis a. albopunctata* (Goeze, 1778)	LC		North-west Italy
50	***Platycleis concii* Galvagni, 1959**	LC	E	Sicily
51	*Platycleis e. escalerai* Bolívar, 1899	LC		Central-south Italy
52	*Platycleis falx laticauda* Brunner, 1882	VU		South Italy and Sicily
53	*Platycleis grisea grisea* (Fabricius, 1781)	LC		Italian peninsula, Sicily, and Sardinia
54	*Platycleis i. intermedia* (Serville, 1839)	LC		Italian peninsula, Sicily, and Sardinia
55	***Platycleis ragusai* Ramme, 1927**	LC	E	Sicily

56	*Platycleis romana* Ramme, 1927	LC		Italian peninsula
57	*Platycleis sabulosa* Azam, 1901	LC		South Italy, Sicily, and Sardinia
58	***Sardoplatycleis galvagnii* (Fontana, Buzzetti et Odé, 2010)**	CR	E	Sardinia
59	***Tessellana lagrecai* Messina, 1978**	VU	E	Sicily
60	***Tessellana nigrosignata* (A. Costa, 1863)**	EN	E	South Italy
61	*Tessellana t. tessellata* (Charpentier, 1825)	LC		Italian peninsula, Sicily, and Sardinia
62	***Incertana drepanensis* (Massa, Fontana et Buzzetti, 2006)**	CR	E	Sicily
63	*Montana m. montana* (Kollar, 1833)	LC		North Italy
64	*Montana stricta* (Zeller, 1849)	LC		Italian peninsula
65	*Metrioptera brachyptera* (Linnaeus, 1761)	LC		North-east Italy
66	***Metrioptera caprai caprai* Baccetti, 1956**	VU	E	Central Apennines
67	***Metrioptera caprai baccettii* Galvagni, 1958**	VU	E	Central Apennines
68	***Metrioptera caprai galvagnii* Baccetti, 1963**	VU	E	North Apennines
69	***Metrioptera caprai lagrecai* Baccetti, 1958**	VU	E	Central Apennines
70	*Metrioptera s. saussuriana* (Frey-Gessner, 1872)	LC		North-west Italy
71	*Bicolorana b. bicolor* (Philippi, 1830)	LC		Italian peninsula
72	*Bicolorana kraussi* (Padewieth, 1900)	NT		Friuli Venezia Giulia
73	*Roeseliana minor* Nadig, 1961	LC		Lombardy, Emilia-Romagna, Piedmont, Liguria, Marche, Tuscany; Switzerland
74	***Roeseliana brunneri* Ramme, 1951**	NT	E	Venetian lagoon
75	*Roeseliana roeselii* (Hagenbach, 1822)	LC		North-east Italy
76	*Zeuneriana abbreviata* (Serville, 1839)	LC		North-west Italy
77	*Zeuneriana marmorata* (Fieber, 1853)	EN		North-east Italy
78	*Sepiana sepium* (Yersin, 1854)	LC		Italian peninsula, Sicily, and Sardinia
79	*Modestana modesta* (Fieber, 1853)	LC		North-east Italy
80	*Pholidoptera a. aptera* (Fabricius, 1793)	LC		Alps
81	***Pholidoptera aptera goidanichi* Baccetti, 1963**	LC	E	Central-north Apennines
82	*Pholidoptera d. dalmatica* (Krauss, 1899)	LC		North-east Italy
83	*Pholidoptera fallax* (Fischer, 1854)	LC		Italian peninsula, Sicily, and Sardinia

84	*Pholidoptera femorata* (Fieber, 1853)	LC		Italian peninsula, Sicily, and Sardinia
85	*Pholidoptera griseoaptera* (De Geer, 1773)	LC		Italian peninsula and Sardinia
86	*Pholidoptera l. littoralis* (Fieber, 1853)	LC		North-east Italy
87	***Pholidoptera littoralis insubrica*** **Nadig, 1961**	LC	E	North-west Alps
88	***Eupholidoptera bimucronata*** **(Ramme, 1927)**	LC	E	Sicily
89	*Eupholidoptera chabrieri* (Charpentier, 1825)	LC		North-west Italy
90	***Eupholidoptera brunneri*** **(Targioni Tozzetti, 1881)**	LC	E	Central Apennine
91	***Eupholidoptera danconai*** **La Greca, 1959**	NT	E	Italian peninsula
92	*Eupholidoptera garganica* La Greca, 1959	NT		Apulia
93	***Eupholidoptera hesperica*** **La Greca, 1959**	LC	E	South Italy
94	***Eupholidoptera magnifica*** **(A. Costa, 1863)**	LC	E	Italian peninsula and Sardinia
95	*Eupholidoptera schmidti* (Fieber, 1861)	LC		Central and north-east Italy
96	***Anonconotus alpinus*** **(Yersin, 1858)**	LC	E	North-west Alps
97	***Anonconotus apenninigenus*** **Targioni Tozzetti, 1881**	CR	E	North Apennines
98	***Anonconotus baracunensis*** **Nadig, 1987**	NT	E	North-west Alps
99	***Anonconotus ghilianii*** **Camerano, 1878**	LC	E	North-west Alps
100	***Anonconotus italoaustriacus*** **Nadig, 1987**	EN	E	North-east Alps
101	***Anonconotus ligustinus*** **Galvagni, 2002**	EN	E	North-west Alps
102	***Anonconotus occidentalis*** **Carron et Wermeille, 2002**	LC	E	North-west Alps
103	***Anonconotus pusillus*** **Carron et Sardet, 2002**	NT	E	North-west Alps
104	***Anonconotus sibyllinus*** **Galvagni, 2002**	EN	E	Central Apennines
105	*Yersinella beybienkoi* La Greca, 1974	LC		Italian peninsula
106	*Yersinella raymondi* (Yersin, 1860)	LC		Italian peninsula, Sicily, and Sardinia
107	*Pachytrachis gracilis* (Brunner, 1861)	LC		North-east Italy
108	*Pachytrachis striolatus* (Fieber, 1853)	LC		North and north-east Italy
109	***Pterolepis elymica*** **Galvagni et Massa, 1979**	EN	E	Sicily
110	*Pterolepis pedata* A. Costa, 1882	LC		Sardinia and island of Lampedusa

111	*Rhacocleis annulata* Fieber, 1853	LC		Central-south Italy, Sicily, and Sardinia
112	**_Rhacocleis baccettii_ Galvagni, 1976**	NT	E	Sardinia
113	*Rhacocleis corsicana* Bonfils, 1960	NT		Sardinia and Corsica
114	**_Rhacocleis japygia_ La Greca, 1959**	EN	E	South Italy
115	*Rhacocleis germanica* (Herrich-Schaeffer, 1840)	LC		Italian peninsula
116	**_Rhacocleis maculipedes_ (Ingrisch, 1983)**	EN	E	Sardinia
117	*Rhacocleis n. neglecta* (A. Costa, 1863)	LC		Italian peninsula and Sicily
118	**_Rhacocleis thyrrhenica_ La Greca, 1952**	NT	E	Tyrrhenian islands of central Italy
119	**_Ctenodecticus b. bolivari_ Targioni Tozzetti, 1881**	LC	E	Sardinia
120	**_Ctenodecticus siculus_ Ramme, 1927**	LC	E	Sicily
121	*Antaxius difformis* (Brunner, 1861)	LC		North Italy
122	*Chopardius p. pedestris* (Fabricius, 1787)	LC		North Italy
123	**_Chopardius pedestris apuanus_ (Nadig, 1958)**	LC	E	Apuane Alps
124	*Saga pedo* (Pallas, 1771)	LC		Italian peninsula, Sicily, and Sardinia
125	**_Ephippiger a. apulus_ (Ramme, 1933)**	LC	E	South Italy
126	**_Ephippiger apulus italicus_ La Greca, 1959**	LC	E	South Italy
127	**_Ephippiger cavannai_ (Targioni Tozzetti, 1881)**	LC	E	South Italy
128	**_Ephippiger perforatus_ Rossi, 1790**	LC	E	Italian peninsula
129	**_Ephippiger camillae_ Fintana et Massa, 2000**	CR	E	Sicily
130	**_Ephippiger carlottae_ Fontana et Odé, 2003**	NT	E	North Apennines
131	*Ephippiger discoidalis* (Fieber, 1853)	LC		North-east Italy
132	**_Ephippiger persicarius_ Fruhstorfer, 1921**	LC	E	North Italy
133	**_Ephippiger terrestris bormansi_ Brunner, 1882**	LC	E	North-west Italy
134	**_Ephippiger terrestris caprai_ Nadig, 1980**	LC	E	North-west Italy
135	**_Ephippiger melisi_ Baccetti, 1958**	EN	E	Central Apennines
136	**_Ephippiger ruffoi_ Galvagni, 1955**	EN	E	Central Apennines
137	**_Ephippiger zelleri_ (Fischer, 1854)**	EN	E	Central Italy
138	*Lucasinova nigromarginata* (Lucas, 1849)	LC		Sicily

139	***Uromenus annae*** (Targioni Tozzetti, 1881)	NT	E	Sardinia
140	*Uromenus b. bonneti* (Bolívar, 1907)	LC		Is. of Lampedusa (Sicily)
141	***Uromenus bonneti painoi* Ramme, 1927**	LC	E	Sicily
142	***Uromenus brevicollis insularis* (Chopard, 1923)**	LC	E	Sardinia and Corsica
143	***Uromenus brevicollis trinacriae* (La Greca, 1964)**	LC	E	Sicily
144	*Uromenus elegans* (Fischer, 1853)	LC		Italian peninsula
145	***Uromenus riggioi* La Greca, 1964**	CR	E	Sicily
146	***Uromenus siculus* (Fieber, 1853)**	LC	E	Sicily
147	*Praephippigera pachygaster* (Lucas, 1849)	DD		Sardinia and North Africa
Rhaphidophoridae				
148	***Dolichopoda aegilion* Baccetti, 1975**	VU	E	Tuscan Archipelago
149	***Dolichopoda azami ligustica* Baccetti et Capra, 1958**	LC	E	Central and north Italy
150	***Dolichopoda azami septentrionalis* Baccetti et Capra, 1959**	LC	E	Tuscany
151	***Dolichopoda baccettii* Capra, 1957**	VU	E	Mt. Argentario, Tuscany
152	***Dolichopoda capreensis* Capra, 1968**	VU	E	Capri Is., Campania
153	***Dolichopoda g. geniculata* (O.G. Costa, 1860)**	LC	E	South Italy
154	***Dolichopoda geniculata pontiana* Capra, 1967**	LC	E	Ponziane Is., Latium
155	***Dolichopoda l. laetitiae* Minozzi, 1920**	LC	E	Central Italy
156	***Dolichopoda laetitiae etrusca* Baccetti et Capra, 1959**	LC	E	Central Italy
157	***Dolichopoda muceddai* Rampini et Di Russo, 2005**	VU	E	Sardinia
158	***Dolichopoda palpata* (Sulzer, 1776)**	DD	E	Calabria and Sicily
159	***Dolichopoda s. schiavazzii* Capra, 1934**	LC	E	Tuscan coast
160	***Dolichopoda schiavazzii caprai* Lanza, 1954**	LC	E	Tuscany
161	***Troglophilus (Troglophilus) a. andreinii* Capra, 1927**	LC	E	South Italy
162	***Troglophilus (Troglophilus) andreinii hydruntinus* La Greca, 1961**	LC	E	Apulia
163	*Troglophilus (Troglophilus) cavicola* (Kollar, 1833)	LC		North-east Italy

164	*Troglophilus (Paratroglophilus) n. neglectus* Krauus, 1879	LC		North-east Italy
165	*Diestrammena (Tachycines) asynamora* (Adelung, 1902)	NA		Italian peninsula and Sicily (introduced)
		Gryllidae		
166	*Nemobius s. sylvestris* (Bosc, 1792)	LC		Central-north Italy, Sardinia
167	*Pteronemobius h. heydenii* (Fischer, 1853)	LC		Italian peninsula, Sicily, and Sardinia
168	*Pteronemobius lineolatus* (Brullé, 1835)	LC		North-west Italy
169	*Stenonemobius gracilis* (Jakovleff, 1871)	DD		Italian peninsula and Sicily
170	*Trigonidium cicindeloides* Rambur, 1839	LC		Italian peninsula, Sicily, and Sardinia
171	*Natula averni* (A. Costa, 1855)	VU		Italian peninsula, Sicily, and Sardinia
172	*Gryllomorpha d. dalmatina* (Ocskay, 1832)	LC		Italian peninsula, Sicily, and Sardinia
173	***Gryllomorpha dalmatina schmidti* Gorochov, 1996**	LC	E	Latium
174	*Gryllomorphella uclensis* (Pantel, 1890)	LC		Italian peninsula, Sicily, and Sardinia
175	***Petaloptila (Italoptila) andreinii* Capra, 1937**	LC	E	Italian peninsula
176	***Petaloptila (Petaloptila) clauseri* (Schmidt, 1991)**	DD	E	North Italy
177	***Petaloptila (Petaloptila) sbordonii* (Baccetti, 1979)**	DD	E	Calabria
178	***Acroneuroptila puddui* Cadeddu, 1970**	VU	E	Sardinia
179	***Acroneuroptila sardoa* Baccetti, 1960**	VU	E	Sardinia
180	*Gryllus bimaculatus* De Geer, 1773	LC		Italian peninsula, Sicily, and Sardinia
181	*Gryllus campestris* Linnaeus, 1758	LC		Italian peninsula, Sicily, and Sardinia
182	*Brachytrupes megacephalus* (Lefèvre, 1827)	VU		Sicily and Sardinia
183	*Melanogryllus d. desertus* (Pallas, 1771)	LC		Italian peninsula and Sicily
184	*Acheta domesticus* (Linnaeus, 1758)	LC		Italian peninsula, Sicily, and Sardinia
185	*Acheta gossypii* O.G. Costa, 1855	DD		Apulia
186	*Acheta hispanicus* Rambur, 1839	LC		South Italy and Sicily
187	*Modicogryllus a. algirius* (Saussure, 1877)	LC		Sicily
188	*Svercus p. palmetorum* (Krauss, 1902)	NT		Calabria, Sicily, and Sardinia
189	*Eumodicogryllus b. bordigalensis* (Latreille, 1804)	LC		Italian peninsula, Sicily, and Sardinia
190	*Grylloderes brunneri* (Riggio, 1888)	NT		Sicily

191	*Oecanthus dulcisonans* Gorochov, 1993	LC		Italian peninsula, Sicily, and Sardinia
192	*Oecanthus p. pellucens* (Scopoli, 1763)	LC		Italian peninsula, Sicily, and Sardinia
Mogoplistidae				
193	*Mogoplistes brunneus* Serville, 1839	LC		Italian peninsula, Sicily, and Sardinia
194	*Paramogoplistes novaki* (Krauss, 1888)	DD		few localities in Sardinia and on the Tyrrhenian coast of Italy
195	*Arachnocephalus vestitus* A. Costa, 1855	LC		Italian peninsula, Sicily, and Sardinia
196	*Pseudomogoplistes squamiger* (Fischer, 1853)	LC		Italian peninsula, Sicily, and Sardinia
Myrmecophilidae				
197	*Myrmecophilus (Myrmecophilus) acervorum* (Panzer, 1799)	LC		North Italy and Sicily
198	*Myrmecophilus (Myrmecophilus) aequispina* Chopard, 1923	LC		North-west Italy
199	*Myrmecophilus (Myrmecophilus) baronii* Baccetti, 1966	NT		Is. of Pantelleria (Sicily); also Malta and Tunisia
200	*Myrmecophilus (Myrmecophilus) fuscus* Stalling, 2013	LC		Sicily
201	*Myrmecophilus (Myrmecophilus) myrmecophilus* (Savi, 1819)	LC		Italian peninsula, Sicily, and Sardinia
202	*Myrmecophilus (Myrmophilina) ochraceus* (Fischer, 1854)	LC		South Italy, Sicily, and Sardinia
Gryllotalpidae				
203	***Gryllotalpa cossyrensis* Baccetti et Capra, 1978**	VU	E	Is. Pantelleria (Sicily)
204	*Gryllotalpa gryllotalpa* (Linnaeus, 1758)	LC		Central-north Italy
205	***Gryllotalpa octodecim* Baccetti et Capra, 1978**	DD	E	North-west Italy, Sardinia
206	***Gryllotalpa quindecim* Baccetti et Capra, 1978**	LC	E	South Italy, Sicily
207	***Gryllotalpa sedecim* Baccetti et Capra, 1978**	LC	E	North-west Italy, Sardinia
208	*Gryllotalpa septemdecimchromosomica* Ortiz, 1958	DD		Central and north-west Italy
209	***Gryllotalpa viginti* Baccetti et Capra, 1978**	DD	E	Liguria
210	***Gryllotalpa vigintiunum* Baccetti, 1991**	DD	E	Sardinia
Tetrigidae				
211	*Paratettix meridionalis* (Rambur, 1838)	LC		Italian peninsula, Sicily, Sardinia

212	*Tetrix b. bipunctata* (Linnaeus, 1758)	LC		North Italy
213	*Tetrix bipunctata kraussi* (Saulcy, 1888)	LC		Italian peninsula, Sicily, and Sardinia
214	*Tetrix bolivari* (Saulcy, 1901)	LC		North-east and South Italy
215	*Tetrix ceperoi* (Bolívar, 1887)	LC		Italian peninsula, Sicily, and Sardinia
216	*Tetrix depressa* (Brisout de Barneville, 1848)	LC		Italian peninsula, Sicily, and Sardinia
217	*Tetrix subulata* (Linnaeus, 1758)	LC		Italian peninsula, Sicily, and Sardinia
218	*Tetrix tenuicornis* (Sahlberg, 1893)	LC		Central and north Italy
219	*Tetrix tuerki* (Krauss, 1876)	VU		North Italy
	Trydactilidae			
220	*Xya variegata* (Latreille, 1809)	LC		Italian peninsula
	Pyrgomorphidae			
221	*Pyrgomorpha c. conica* (Olivier, 1791)	LC		Sicily and Sardinia
	Pamphagidae			
222	***Pamphagus marmoratus* Burmeister, 1838**	LC	E	Sicily
223	***Pamphagus ortolanii* Cusimano et Massa, 1977**	NT	E	Is. of Lampedusa (Sicily)
224	***Pamphagus sardeus* (Herrich-Schaeffer, 1840)**	LC	E	Sardinia
225	*Acinipe calabra* (O.G. Costa, 1828)	LC		Calabria, Sicily
226	***Acinipe galvagnii* Cusimano et Massa, 1977**	NT	E	Egadi Is. and west Sicily
227	*Ocneridia nigropunctata* (Lucas, 1849)	LC		Sicily
228	***Prionotropis appula* (O.G. Costa, 1836)**	LC	E	South Italy
229	*Prionotropis hystrix* (Germar, 1817)	VU		North-east Italy
	Acrididae			
230	***Podisma d. dechambrei* Leproux, 1951**	LC	E	North-west Italy
231	***Podisma dechambrei melisi* Baccetti, 1954**	LC	E	Apuane Alps, Tuscan-Emilian Apennines
232	***Podisma eitschbergeri* Harz, 1973**	DD	E	Piedmont
233	***Podisma emiliae* Ramme, 1926**	CR	E	Tuscan-Emilian Apennines
234	***Podisma goidanichi* (Baccetti, 1958)**	EN	E	Gran Sasso, central Apennines
235	***Podisma magdalenae* Galvagni, 1971**	CR	E	Marche
236	*Podisma p. pedestris* (Linnaeus, 1758)	LC		North Italy

237	***Podisma pedestris caprai*** **Salfi, 1935**	LC	E	Piedmont
238	***Podisma pedestris nadigi*** **Harz, 1975**	LC	E	Alps
239	***Podisma ruffoi*** **Baccetti, 1971**	EN	E	Central Apennines
240	***Podisma silvestrii*** **Salfi, 1935**	CR	E	Central Apennines
241	*Bohemanella f. frigida* (Bohemann, 1846)	LC		North Italy
242	***Italopodisma a. acuminata*** **(La Greca, 1969)**	LC	E	Mt. Greco and Mt. Pratello, Abruzzo
243	***Italopodisma acuminata marsicana*** **(La Greca, 1969)**	LC	E	Mt. Capraro, Mt. Marsicano, Mt. Palombo, Abruzzo
244	***Italopodisma baccettii*** **(La Greca, 1969)**	CR	E	Gran Sasso, Central Apennines
245	***Italopodisma costae*** **(Targioni Tozzetti, 1881)**	LC	E	Mt. Morrone Majella, Mt. Majelletta, Abruzzo
246	***Italopodisma ebneri*** **(La Greca, 1954)**	CR	E	Reatini Mts., Latium
247	***Italopodisma fiscellana*** **(La Greca, 1954)**	EN	E	Central Apennines
248	***Italopodisma lagrecai*** **(Galvagni, 1973)**	CR	E	Central Apennines
249	***Italopodisma lucianae*** **(Baccetti, 1959)**	CR	E	Mt. Majella, Central Apennines
250	***Italopodisma samnitica*** **(La Greca, 1954)**	EN	E	Central Apennines
251	***Italopodisma t. trapezoidalis*** **(La Greca, 1966)**	EN	E	La Meta Mts., Central Apennines
252	***Italopodisma trapezoidalis aprutiana*** **(La Greca, 1969)**	EN	E	Mt. Marsicano, Abruzzo
253	***Italopodisma trapezoidalis curvula*** **(La Greca, 1969)**	EN	E	Ernici and Simbruini Mts., Central Apennines
254	***Epipodisma pedemontana*** **(Brunner, 1882)**	LC	E	Northern Alps
255	***Kisella alpina*** **(Kollar, 1833)**	LC	E	North-western Alps
256	***Kisella irena*** **(Fruhstorfer, 1921)**	LC	E	North-eastern Alps
257	***Kisella subalpina*** **(Fischer, 1850)**	LC	E	Aosta Valley
258	***Nadigella f. formosanta*** **(Fruhstorfer, 1921)**	LC	E	North Italy
259	***Nadigella formosanta bessae*** **Nadig, 1989**	LC	E	Eastern Alps
260	***Pseudoprumna baldensis*** **(Krauss, 1883)**	EN	E	Central Alps
261	*Micropodisma salamandra* (Fischer, 1854)	LC		North-eastern Alps
262	***Chortopodisma cobellii*** **(Krauss, 1883)**	EN	E	North-eastern Alps
263	*Pseudopodisma fieberi* (Scudder, 1898)	LC		North-eastern Alps
264	***Odontopodisma decipiens insubrica*** **Nadig, 1980**	LC	E	North-western Alps

265	*Odontopodisma fallax* Ramme, 1951	LC		North-eastern Alps
266	*Odontopodisma schmidti* (Fieber, 1853)	LC		North-eastern Alps
267	*Pezotettix giornae* (Rossi, 1794)	LC		Italian Peninsula, Sicily, and Sardinia
268	*Calliptamus b. barbarus* (O.G. Costa, 1836)	LC		Italian Peninsula, Sicily, and Sardinia
269	*Calliptamus i. italicus* (Linnaeus, 1758)	LC		Italian Peninsula, Sicily, and Sardinia
270	*Calliptamus siciliae* Ramme, 1927	LC		Italian Peninsula, Sicily, and Sardinia
271	*Calliptamus wattenwylianus* (Pantel, 1896)	LC		Liguria
272	*Eyprepocnemis p. plorans* (Charpentier, 1825)	LC		South Italy, Sicily, and Sardinia
273	*Heteracris adspersa massai* Galvagni, 1978	VU		Sicily and Sardinia
274	*Heteracris annulosa* (Walker, 1870)	EN		Sicily and Sardinia
275	*Anacridium aegyptium* (Linnaeus, 1764)	LC		Italian Peninsula, Sicily, and Sardinia
276	*Schistocerca gregaria* (Forskål, 1775)	LC		Occasional throughout all Italy
277	*Tropidopola c. cylindrica* (Marshall, 1836)	VU		Central-south Italy, Sicily, and Sardinia
278	***Tropidopola graeca transjonica* La Greca, 1964**	VU	E	South Italy
279	*Acrida ungarica mediterranea* Dirsh, 1949	LC		Italian Peninsula, Sicily, and Sardinia
280	*Acrida turrita* Linnaeus, 1758	LC		Central Italy, Sicily, and Sardinia
281	*Truxalis nasuta* (Linnaeus, 1758)	LC		Central Italy, Sicily, and Sardinia
282	*Calephorus compressicornis* (Latreille, 1804)	LC		South Italy and Sicily
283	*Psophus stridulus* (Linnaeus, 1758)	LC		Central-north Italy
284	*Bryodemella t. tuberculata* (Fabricius, 1780)	VU		Lombardy and Liguria
285	*Celes v. variabilis* (Pallas, 1771)	NT		North-east Italy
286	*Locusta migratoria cinerascens* Fabricius, 1781	LC		Italian Peninsula, Sicily, and Sardinia
287	*Oedaleus d. decorus* (Germar, 1826)	LC		Italian Peninsula, Sicily, and Sardinia
288	*Oedaleus senegalensis* (Krauss, 1877)	LC		Sardinia
289	*Oedipoda c. caerulescens* (Linnaeus, 1758)	LC		Italian Peninsula and Sicily
290	***Oedipoda caerulescens sardeti* Defaut, 2006**	LC	E	Sardinia and Corsica
291	***Oedipoda cynthiae* Fontana, Buzzetti et Massa, 2019**	VU?	E	South Italy (Apulia)

292	*Oedipoda f. fuscocincta* Lucas, 1849	LC		South Italy and Sicily
293	***Oedipoda fuscocincta morini*** **Defaut, 2005**	LC	E	Sardinia and Corsica
294	*Oedipoda g. germanica*[1] (Latreille, 1804)	LC		Italian peninsula and Sicily
295	*Oedipoda miniata mauritanica* Lucas, 1849	LC		Sicily and Sardinia
296	*Sphingonotus caerulans caerulans* (Linnaeus, 1767)	LC		Italian peninsula and Sicily
297	***Sphingonotus c. candidus*** **A. Costa, 1888**	NT	E	Sardinia
298	*Sphingonotus corsicus* Chopard, 1924	LC		Sardinia and Corsica
299	*Sphingonotus e. eurasius* Mishtshenko, 1936	DD		Is. of Lampedusa (Sicily)
300	*Sphingonotus obscuratus lameerei* Finot, 1902	NA		Is. of Lampedusa (Sicily)
301	***Sphingonotus personatus*** **Zanon, 1926**	EN	E	Italian peninsula and Sicily
302	*Sphingonotus r. rubescens* (Walker, 1870)	LC		Sardinia and Is. of Lampedusa (Sicily)
303	***Sphingonotus uvarovi*** **Chopard, 1924**	EN	E	Sardinia and Corsica
304	*Acrotylus fischeri* Azam, 1901	LC		North-west Italy
305	*Acrotylus i. insubricus* (Scopoli, 1786)	LC		Italian Peninsula, Sicily, and Sardinia
306	*Acrotylus longipes* (Charpentier, 1845)	NT		South Italy and Sicily
307	*Acrotylus patruelis* (Herrich-Schaeffer, 1838)	LC		Italian Peninsula, Sicily, and Sardinia
308	*Aiolopus s. simulatrix* (Walker, 1870)	DD		Sardinia
309	*Aiolopus s. strepens* (Latreille, 1804)	LC		Italian Peninsula, Sicily, and Sardinia
310	*Aiolopus t. thalassinus* (Fabricius, 1781)	LC		Italian Peninsula, Sicily, and Sardinia
311	*Epacromius c. coerulipes* (Ivanov, 1887)	NT		North-east Italy
312	*Epacromius t. tergestinus* (Charpentier, 1825)	LC		North-east Italy
313	*Epacromius tergestinus ponticus* Karny, 1907	LC		Veneto
314	*Platypygius platypygius* (Pantel, 1886)	EN		Sicily and Sardinia
315	*Mecostethus p. parapleurus* (Hagenbach, 1822)	LC		North Italy
316	*Stethophyma grossum* (Linnaeus, 1758)	LC		North Italy
317	*Paracinema tricolor bisignata* (Charpentier, 1825)	LC		Italian Peninsula, Sicily, and Sardinia)

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[1] Molecular studies have shown that in Italy *O. germanica* is represented by two species, the true *O. germanica*, living north of the Po river, and a probable new species, up to date undescribed, in the rest of the Italian peninsula (Axel Hochkirch, pers. comm.).

318	*Duroniella lucasii* (Bolívar, 1881)	LC		Sardinia
319	*Brachycrotaphus tryxalicerus* (Fischer, 1854)	LC		Sicily and Aeolian Is.
320	**_Ochrilidia nuragica_ Massa, 1994**	EN	E	Sardinia
321	**_Ochrilidia sicula_ (Salfi, 1931)**	EN	E	Sicily
322	*Arcyptera (Arcyptera) fusca* (Pallas, 1773)	LC		Central-north Italy
323	**_Arcyptera (Pararcyptera) alzonai_ Capra, 1938**	EN	E	North-west Alps
324	*Arcyptera (Pararcyptera) m. microptera* (Fischer, 1833)	LC		Friuli Venezia Giulia and south Italy
325	*Ramburiella turcomana* (Fischer, 1846)	LC		South Italy
326	**_Chrysochraon beybienkoi_ Galvagni, 1968**	CR	E	Calabria
327	*Chrysochraon d. dispar* (Germar, 1835)	LC		North-east Italy
328	*Chrysochraon dispar giganteus* Harz, 1975	LC		North-east Italy
329	*Euthystira brachyptera* (Ocskay, 1826)	LC		Alps and Apennines
330	*Dociostaurus g. genei* (Ocskay, 1832)	LC		Italian peninsula
331	*Dociostaurus jagoi occidentalis* Soltani, 1978	LC		Sardinia
332	*Dociostaurus maroccanus* (Thunberg, 1815)	LC		Central-south Italy, Sicily, and Sardinia
333	**_Dociostaurus minutus_ La Greca, 1962**	EN	E	Sicily
334	*Omocestus (Omocestus) rufipes* (Zetterstedt, 1821)	LC		Italian Peninsula, Sicily, and Sardinia
335	*Omocestus (Omocestus) viridulus* (Linnaeus, 1758)	LC		Alps and northern Apennines
336	*Omocestus (Omocestus) africanus* Harz, 1970	LC		Is. of Pantelleria (Sicily)
337	*Omocestus (Omocestus) h. haemorrhoidalis* (Charpentier, 1825)	LC		Italian peninsula
338	**_Omocestus (Omocestus) lopadusae_ La Greca, 1973**	LC	E	Is. of Lampedusa (Sicily)
339	*Omocestus (Omocestus) Petraeus* (Brisout, 1855)	LC		Italian peninsula and Sardinia
340	*Omocestus (Omocestus) raymondi* (Yersin, 1863)	LC		Liguria, Latium, and Calabria
341	**_Omocestus (Omocestus) uvarovi_ Zanon, 1926**	EN	E	South Italy

342	***Stenobothrus apenninus* Ebner, 1915**	LC	E	Apennines
343	***Stenobothrus cotticus* (Kruseman et Jeekel, 1967)**	NT	E	North-western Alps
344	*Stenobothrus fischeri* (Eversmann, 1848)	LC		Alps and Apennines
345	*Stenobothrus l. lineatus* (Panzer, 1796)	LC		Italian peninsula and Sicily
346	*Stenobothrus n. nigromaculatus* (Herrich-Schaeffer, 1840)	LC		Italian peninsula
347	*Stenobothrus rubicundulus* Kruseman et Jeekel, 1967	LC		Central-north Italy
348	*Stenobothrus s. stigmaticus* (Rambur, 1838)	LC		North-east Italy
349	***Stenobothrus ursulae* Nadig, 1986**	VU	E	North-western Alps
350	*Gomphocerus s. sibiricus* (Linnaeus, 1767)	LC		Alps and Apennines
351	*Gomphocerippus rufus* (Linnaeus, 1758)	LC		Italian peninsula and Sardinia
352	*Aeropedellus v. variegatus* (Fischer, 1846)	EN		Alps
353	*Myrmeleotettix m. maculatus* (Thunberg, 1815)	LC		Italian peninsula and Sicily
354	*Stauroderus s. scalaris* (Fischer, 1846)	LC		Alps and Apennines
355	*Pseudochorthippus montanus* (Charpentier, 1825)	LC		Trentino Alto Adige
356	*Pseudochorthippus p. parallelus* (Zetterstedt, 1821)	LC		Alps and Apennines
357	*Chorthippus (Chorthippus) dichrous* (Eversmann, 1859)	LC		Central Italy
358	*Chorthippus (Chorthippus) d. dorsatus* (Zetterstedt, 1821)	LC		Central-North Italy, Sardinia
359	***Chorthippus (Chorthippus) dorsatus garganicus* Jannone, 1937**	LC	E	Apulia
360	***Chorthippus (Chorthippus) karelini bruttius* Fontana et La Greca, 1999**	LC	E	South Italy
361	***Chorthippus (Glyptobothrus) a. alticola* Ramme, 1921**	LC	E	North-eastern Alps
362	*Chorthippus (Glyptobothrus) a. apricarius* (Linnaeus, 1758)	LC		Central-north Italy
363	*Chorthippus (Glyptobothrus) b. biguttulus* (Linnaeus, 1758)	LC		North Italy
364	*Chorthippus (Glyptobothrus) bornhalmi* Harz, 1971	LC		Carso Triestino (Friuli Venezia Giulia)
365	*Chorthippus (Glyptobothrus) b. brunneus* (Thunberg, 1815)	LC		Italian peninsula and Sardinia

366	***Chorthippus (Glyptobothrus) brunneus raggei* (La Greca, Di Mauro, Viglianisi et Monello, 2000)**	LC	E	Sicily
367	***Chorthippus (Glyptobothrus) cialancensis* Nadig, 1986**	LC	E	North-western Alps
368	*Chorthippus (Glyptobothrus) eisentrauti* Ramme, 1931	LC		North Italy
369	***Chorthippus (Glyptobothrus) messinai* (La Greca, Di Mauro, Viglianisi et Monello, 2000)**	LC	E	Sicily
370	***Chorthippus (Glyptobothrus) mollis ignifer* Ramme, 1923**	LC	E	Northern Alps
371	*Chorthippus (Glyptobothrus) pullus* (Philippi, 1830)	LC		North Italy
372	***Chorthippus (Glyptobothrus) rubratibialis* Schmidt, 1978**	LC	E	Italian peninsula
373	***Chorthippus (Glyptobothrus) saulcyi daimei* (Azam, 1893)**	LC	E	North-western Alps
374	***Chorthippus (Glyptobothrus) trinacriae* (La Greca, Di Mauro, Viglianisi et Monello, 2000)**	LC	E	Sicily
375	*Chorthippus (Glyptobothrus) v. vagans* (Eversmann, 1848)	LC		Italian peninsula
376	***Italohippus albicornis* (La Greca, 1948)**	EN	E	Central Apennines
377	***Italohippus modestus* (Ebner, 1915)**	VU	E	Central Apennines
378	***Italohippus monticola* (Ebner, 1915)**	EN	E	Central Apennines
379	***Euchorthippus albolineatus siculus* Ramme, 1927**	LC	E	Sicily
380	*Euchorthippus declivus* (Brisout, 1848)	LC		Italian peninsula and Sardinia
381	*Euchorthippus elegantulus* Zeuner, 1940	LC		Liguria
382	***Euchorthippus sardous* Nadig in Nadig et Nadig, 1933**	LC	E	Sardinia

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Rediscovery of *Volvulella volvulaeformis* (G. Seguenza, 1879) in the Italian Pliocene (Gastropoda Rhizoridae)

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ABSTRACT A fossil gastropod for the Italian Pliocene is here reported. Following bibliographical research, it is assigned to a taxon previously described and never cited: *Cylichna volvulaeformis* G. Seguenza, 1880, which, according to its morphological characteristics, is assigned to the genus *Volvulella* Newton, 1891 (Gastropoda Rhizoridae).

KEY WORDS Gastropoda; Rhizoridae; Pliocene.

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INTRODUCTION

Malacological research carried in the Italian Pliocene led to the discovery of some specimens of a Rhizoridae Dell, 1952, previously described as *Volvulella* sp. in Brunetti & Cresti, 2019. The subsequent examination of numerous literature led to the determination of the specimens examined as *Cylichna volvulaeformis* G. Seguenza, 1880, described by the author for the Pliocene of Calabria, which is now assigned to the genus *Volvulella* Newton, 1891.

MATERIAL AND METHODS

The examined material was collected manually in the ground, on the surface. The following abbreviations are used in the text: H = total height of the shell; CCM = Cresti Massimo collection (Florence, Italy). For suprageneric and generic attributions, the WoRMS was followed (http://www.marinespecies.org/).

RESULTS

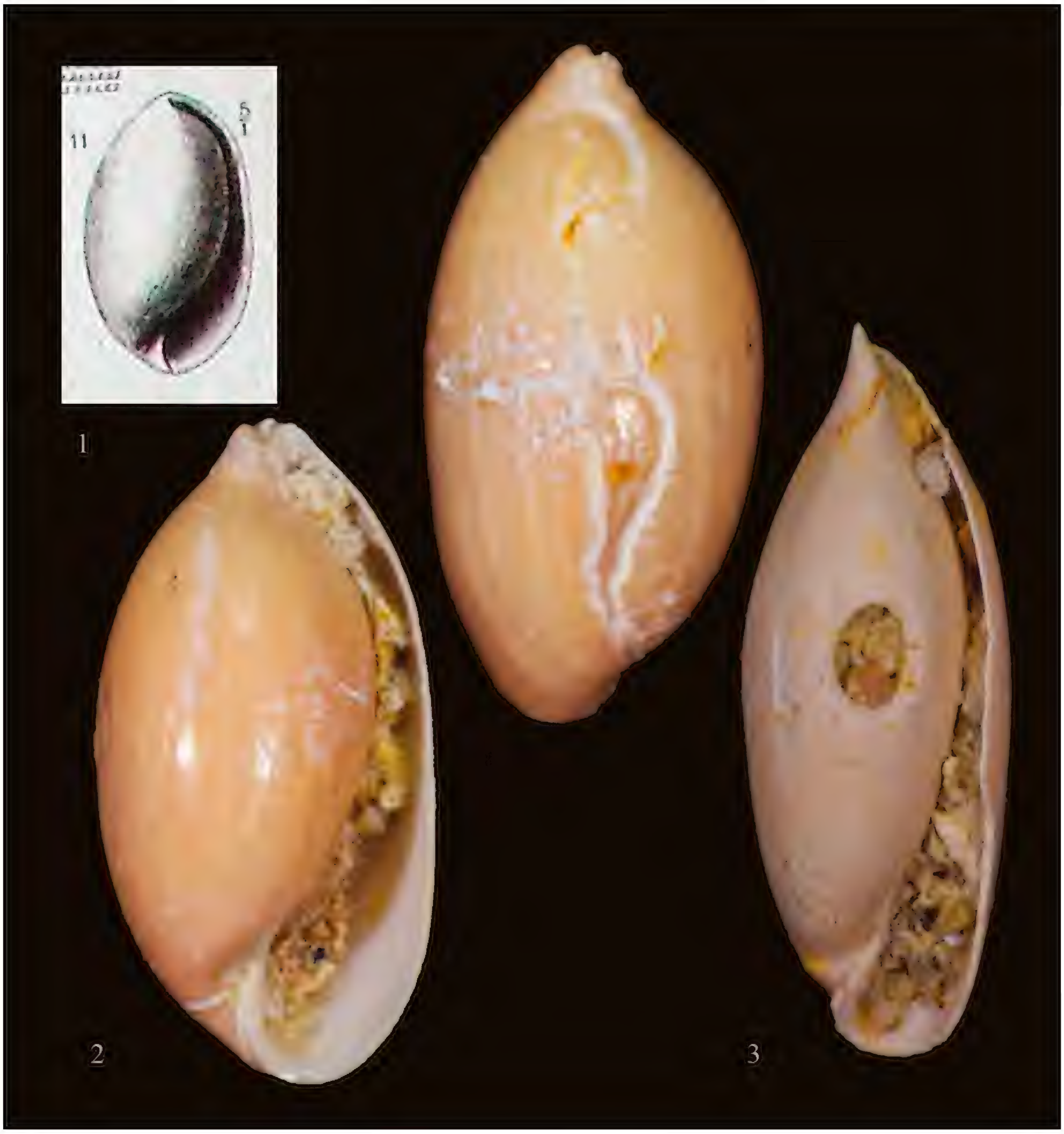
Systematics

Classis GASTROPODA Cuvier, 1795
Ordo CEPHALASPIDEA P. Fischer, 1883
Superfamilia BULLOIDEA Gray, 1827
Familia RHIZORIDAE Dell, 1952
Genus *Volvulella* Newton, 1891
type species: *Bulla acuminata* Bruguiere, 1792

Volvulella volvulaeformis (G. Seguenza, 1879) (Figs. 1, 2)

Cylichna volvulaeformis G. Seguenza, 1880: p. 252, tav. 16, fig. 11.
Volvulella sp. Brunetti & Cresti, 2019: p. 116, fig. 520.

ORIGINAL DIAGNOSIS. G. Seguenza, 1880: "17. *C. volvulaeformis *n. sp. Tav. XVI. fig. 11. Testa ovata, antice rotundata, postice subacuta: columella subarcuata, fisuram umbìlicalem constituens: os strìctum, arcuatum, antice elargatum, postice gradatim attenuatum*".



Figures 1, 2. *Volvulella volvulaeformis* (G. Seguenza, 1879). Fig. 1: original figure from Seguenza (1879), H = 5 mm. Fig. 2: Orciano Pisano (Pisa), Piacenzian, H = 3 mm (CCM). Figure 3. *Volvulella acuminata* (Bruguière, 1792) Orciano Pisano (Pisa), Piacenzian, H = 4 mm (CCM).

DESCRIPTION. Shell with maximum dimensions <5 mm. Oval shape, with thin shell, convex sides, pointed apex. The shell is formed entirely from the last whorl. Aperture rear wide, narrows to two thirds of the whorl, with thin, sharp lip. Rounded front end, narrow navel, partially closed. Columellar callus slightly extended, there is a hint of plica inside. Sculpture composed of thin spiral grooves more evident at the ends, absent in the center of the shell.

REMARKS. I think it is interesting to propose the author's observations on this taxon. This species is very distinctive for its shape, which does not present any parting to the posterior region, and which instead protrudes and is almost acute. It appears to be carved from the mouth which continues to be narrower and narrower until to the extreme part. This character is found in the genus *Volvula*, and therefore this species is to be considered as a link between it and the *Cylichna* (G. Seguenza, 1879: 253).

This species is easily recognizable for the characteristic oval shape at the base with the pointed apex. The most similar species is *Volvulella acuminata* (Bruguière, 1792) (Fig. 3) which differs from *V. volvulaeformis* (G. Seguenza, 1879) for the shape of the narrowest shell, the thinnest and most pointed apex, the different shape of the lip. The species had recently been iconographed as *Volvulella* sp. by Brunetti & Cresti (2019).

The material examined consists of 6 specimens from the Piacenziano of Orciano Pisano (Pisa). Another specimen, unfortunately destroyed, was found by the writer in the middle Pliocene of the Rio Crevalese (Piacenza). The specimen shown by G. Seguenza (1879) (Fig. 1) had been found in the locality "Astian" of Gallina (Reggio Calabria) from which most of the species established by G. Seguenza came, unfortunately destroyed due to the Messina earthquake of 1901. The locality "Astian" of Gallina includes a chronostratigraphic interval that varies from late Pliocene to the early Pleistocene (La Perna & d'Abramo 2010). We agree with Bertolaso & Palazzi (2000) whether or not to establish a neotype against this possibility if not in possession of topotypical material, absent in this case.

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On the presence of the alien exotic sap beetle *Phenolia (Lasiodites) picta* (Macleay, 1825) (Coleoptera Nitidulidae) in Italy

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ABSTRACT The exotic sap beetle *Phenolia (Lasiodites) picta* (W.S. Macleay, 1825) (Coleoptera Nitidulidae) is an alien species recently recorded in Europe (Spain, France, and Greece), and Turkey. For Italy, only a single record of *P.* cf. *picta* is reported from Sicily. In this paper, we studied this specimen confirming the presence of *P. picta* in Italy.

KEY WORDS Alien species; *Phenolia*; Nitidulidae; Sicily.

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INTRODUCTION

The problem of alien species has always been present in past centuries and has been linked to the various activities of man on our planet. However, in recent decades this phenomenon has multiplied and, often, has become detached from the presence of man, following its own dynamics and characteristics that are not always easily understood and have a great environmental impact.

Insects are one of the groups most affected by this phenomenon and there are now numerous reports of these invasive species in Europe (Roques et al., 2009). Among the Coleoptera, the Nitidulidae family includes numerous species introduced in Europe and in the Mediterranean area (Jelinek et al., 2016).

The nitidulid genus *Phenolia* Erichson, 1843 is the one that presents a wider distribution with two species listed also in Europe: *P. tibialis* (Boheman, 1851) and *P. picta* (W.S. Macleay, 1825) (see Jelínek et al., 2016).

Particularly, *P. picta* has been introduced into Spain, France, Greece, and Turkey (Jelinek & Audisio, 2007; Vinolas et al., 2014, as *Phenolia limbate tibialis*; Montagud & Orrico, 2015; Jelinek et al., 2016; Kalaentzis et al., 2019) (Fig. 1). Currently, there are no record of this species in Italy, except for the online reporting of a specimen of *P.* cf. *picta* sampled in Sicily (Ditta, 2019).

In this paper, we report the study of this specimen that allowed us to identify it as *P. picta* and, therefore, to confirm the presence of this species in Sicily and Italy.

RESULTS

Systematics

Ordo COLEOPTERA
Subordo POLYPHAGA Emery, 1886
Familia NITIDULIDAE Latreillae, 1802
Subfamilia NITIDULINAE Latreillae, 1802

genus *Phenolia* Erichson, 1843
Subgenus *Lasiodites* Jelínek, 1999

Phenolia picta (W.S. Macleay, 1825)

EXAMINED MATERIAL. Italy, Sicily, Mazara del Vallo, near gorgo Basso of the Riserva Lago Preola, 2.XI.2019, 1 male, legit A. Ditta.

DESCRIPTION. Male (Fig. 2). Length 7.4 mm; maximum width (at the base of the pronotum) 4.1 mm. Dark brown in colour with the light yellowish elytral band formed by the union of some of the light small elytral spots, distinctively bicoloured femora (light and dark brown). The posterior pronotal angles not projecting backwardly. Pro- and mesotibiae sub-rectilinear, not sinuate. Aedeagus as in figure 3.

DISTRIBUTION AND BIOLOGY. *Phenolia picta* is an invasive species with Oriental and Palaeotropical area of origin. It is widespread in Madagascar, Mauritius, Nosy Be, Reunion, and Seychelles, Australian and Indomalayan regions, eastern Palaearctic zone (including Korea, China, Japan, and Pakistan), Hawaii, and is probably also present in Polynesia (Montagud & Orrico, 2015). In Europe and Mediterranean areas, it has been introduced into Spain, France, Greece, and Turkey (Jelinek & Audisio, 2007; Vinolas et al., 2014, as *Phenolia limbata tibialis*; Montagud & Orrico, 2015; Jelinek et al., 2016; Viñolas & Muñoz Batet, 2017; Kalaentzis et al., 2019).

Phenolia picta lives exclusively on fruits in the advanced stage of maturity that have already fallen to the ground (Marthur et al., 1958; Delobel & Tran, 1993; NZS Bio Pineapple Th., 2001; Abdullah & Shamsulaman, 2008; Hishike et al., 2009; Naka et al., 2010).

Montagud & Orrico (2015) have conducted interesting observations on the biology of this species in Spain which they found in nature on the ripe and fallen fruits of fig (*Ficus carica*), prickly pear (*Op-*

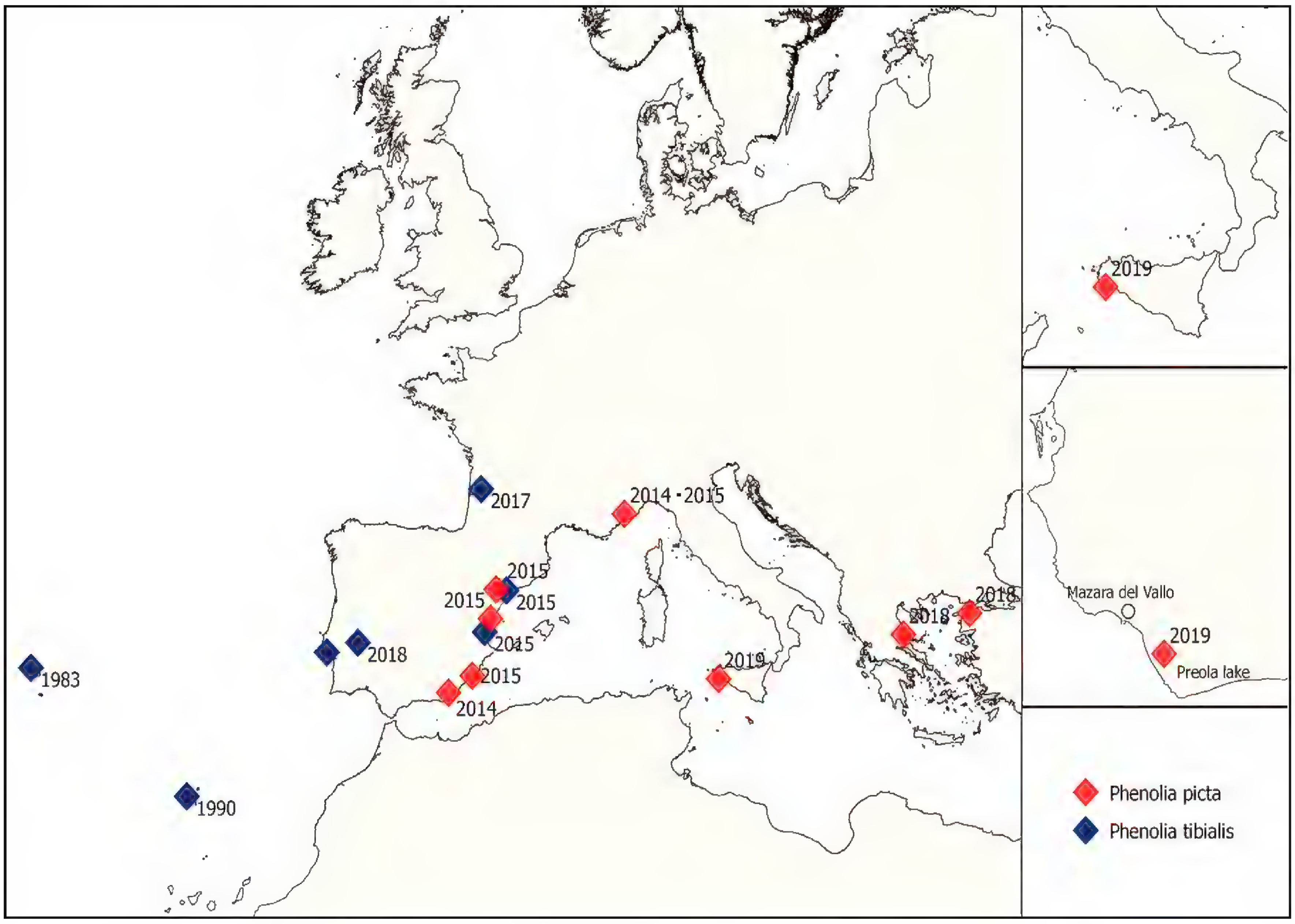
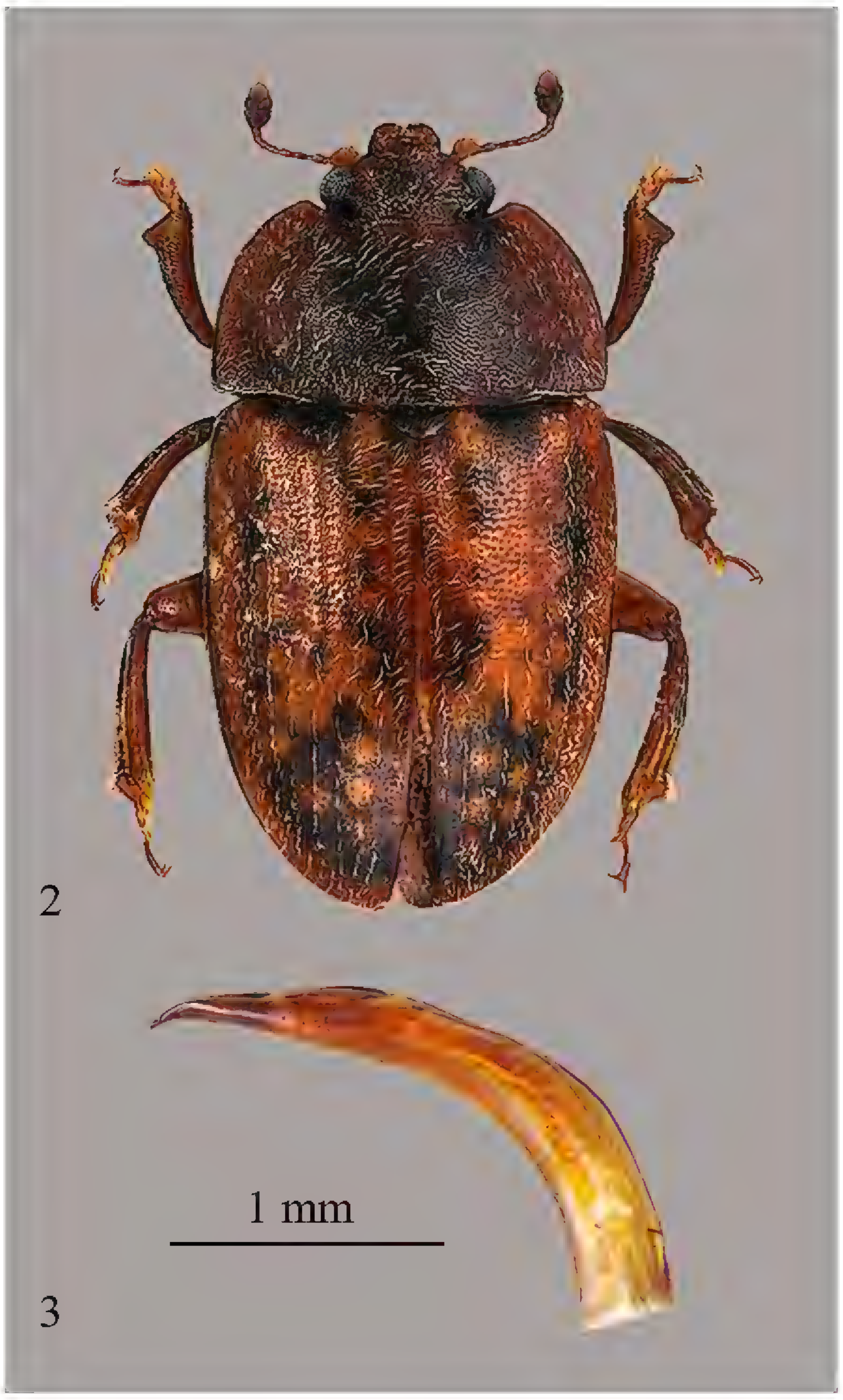


Figure 1. Map showing previous published records of *Phenolia (Lasiodites) picta* and *P. (Lasiodites) tibialis* in Europe and Turkey (see text), and our new record of the species in Italy.



Figures 2, 3. *Phenolia (L.) picta* male from Sicily, length 7.4 mm. (Fig. 2), with aedeagus (Fig. 3).

untia sp.), vine (*Vitis vinifera*), and oranges (*Citrus* sp.). These authors observed *P. picta* and *P. tibialis* living in different locations and managed to breed them in the laboratory by making further observations on their biology and larval morphology.

Introduced populations of *P. picta* have been observed to coexist with other native species of nitidulids in several localities (Viñolas et al., 2014; Montagud & Orrico, 2015).

REMARKS. *Phenolia picta* is very similar to *P. tibialis*, other alien species recently introduced into Europe but not reported from Italy (Jelinek et al., 2016). *Phenolia tibialis* has the very transverse pronotum covered by strong and dense punctuation with broad base and posterior pronotal angles moderately projecting backwardly, darker elytra with aligned bristles, pro- and mesotibiae strongly sinuous in their distal part in the male, aedeagus with the apex of the parameters shorter and less pointed.

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Beyond the audible: wide band (0-125 kHz) field investigation on Italian Orthoptera (Insecta) songs

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ABSTRACT In recent years, several species of Orthoptera were field recorded by the authors by using a low cost USB microphone with a sampling frequency up to 250 kHz. Here for the first time we propose a comprehensive review of the audio samples obtained, including envelopes, spectrograms and frequency analyses, to reveal their extension into the ultrasonic domain. Our research both extends previous similar efforts, such as the paper by Heller (1988) and covers for the first time several species for which ultrasound recordings are not reported in scientific literature.

KEY WORDS Ultrasound; Bioacoustics; Ultramic.

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INTRODUCTION

Importance of bioacoustic studies is manifold and increasing, primarily in taxonomy and systematic (Tishechkin, 2014), conservation (Laiolo, 2010) and biodiversity research (Obrist et al., 2010; Sugai & Llusia, 2018).

The Orthoptera fauna of Italy is summarized in Massa et al. (2012), with information on acoustic emissions limited to audible frequencies. In the early 2010's, field recording techniques were revolutionized by the emergence of low-cost, highly portable USB microphones with a sampling rate of 250 kHz, and thus capable to provide monophonic recordings in the 1- 125 kHz range. Since then, in the spirit of Dave Gray's Liminal Thinking (Gray, 2016), the authors - in the steps of Heller (1988) and of all the investigators who ventured in the inaudible realm in the last thirty years - have been constantly trying to overcome anthropocentric cognitive and perceptive biases, by aiming at an objective representation of animal sounds thanks to the deployment of the flexible and relatively cheap field recording apparatus mentioned above, that allows a much wider frequency range extended in the inaudible ultrasonic range.

Based on field recordings obtained with the Ultramic 250 by Dodotronic, our previous papers (Brizio & Buzzetti, 2014; Brizio, 2018; Buzzetti et al., 2019), illustrated some technical limitations of Ultramic 250 (including the emergence of characteristic, extremely narrow intrinsic noise bands for USB cable lengths higher than 50 cm), and defined a protocol for the comparison of digital audio recordings taken at 250 kHz and digital recordings obtained at any lower sampling frequency, down to 44.1 kHz sampling. Those previous works confirmed the consistency of the results obtained with both techniques, and the possibility to identify different species on the basis of their song, as well as to derive novel information from an analysis of the high frequency components of the songs, some of which previously unreported in the scientific literature.

Our exploration of the inaudible range builds upon well-known foundations, such as the monograph by Heller (1988). If compared to that reference book, this paper includes previously uncovered species, particularly of infraorder Gryllidea. Even though it covers just a small fraction of the species covered by Heller (1988), this paper investigates a range up to 125 kHz, provides better quality illustrations of the frequency analyses, as well as time/frequency spectrograms, and in that respect it improves the results in Heller's monograph.

The instrumentation used for our work is far cheaper and easier to use than the bulky, complex and expensive equipment used by Heller (1988). The technological development of the last 30 years allow a new and easier approach to full bandwidth recording of Orthopterans, to better investigate in the intimate structure of their sounds and also to open new questions.

It should be noted that this paper should be viewed primarily as a commented field report. Our research is primarily focused on field recording and on the spectral characterization of the songs of Orthopteran species.

We didn't investigate issues such as propagation distance of the inaudible components as a whole, or of specific narrow inaudible bands, compared to the propagation distance of audible frequencies. From basic acoustic principles, it can be expected that – besides to the 1/r law of distance damping - the absorption of high frequencies, exhaustively covered e.g. by Vladišauskas & Jakevičius (2004), and by Bass et al. (1984) rises with frequency, temperature and humidity - indicatively, in standard atmosphere it may amount to 5 dB/m for frequencies in the order of magnitude of 100 kHz. We included a column in Table 2, "Recording Distance", from which this datum can be appreciated. Operatively, knowing that the highest frequencies are more sensible to atmospheric dumping, during our field recordings, we strived to get as close as possible to the singing specimens, but we didn't systematically take recordings at different distances for comparative purposes.

It's beyond the scope of this paper to ascertain which parts of the whole spectra effectively engage the hearing apparatus of conspecifics, are heard and consequently elicit a behavioral response. The selective laboratory tests needed, besides the anatomical investigations on a microscopic scale to describe the hearing apparatus, should include a series of experiments to expose living specimens to band-pass filtered versions of the song, a procedure that may allow to determine which frequencies are perceived and which not.

Such investigations may require unaffordable amounts of time, and may pose logistic difficulties for the collection and rearing of a statistically significant number of specimens (no less than 10 or 12 per species, as usual for qualitative analyses - see Shetty, 2019). For those reasons, with the primary aim to provide without any further delay the novel data that we collected, we will restrain the scope of our research to the description of the songs, that will be separately investigated in future species-specific articles.

MATERIAL AND METHODS

All the species listed in Table 1 were recorded in Italy. With the exception of audio samples of *Isophya modestior*, *Barbitistes vicetinus*, *Pholidoptera littoralis littoralis*, *Eupholidoptera* sp. (recorded in the town of Battaglia Terme) and *Uromenus annae*, all the recordings were obtained in nature. Specimens recorded by FMB are deposited in the collection of Fondazione Museo Civico di Rovereto, specimens recorded by CB were identified in the field but not captured.

Ultrasound monophonic recordings at 250 kHz sampling rate were obtained by using a Dodotronic Ultramic 250 microphone connected via USB cable to the recording apparatus, that included, for Author 2, an Asus Eee PC 1000HE notebook PC, a cell phone Samsung Galaxy S5 2014 and an Asus MemoPad ME172V tablet; for CB an Asus Eee PC 1225B notebook pc, using SeaWave software by CIBRA, developed by Author 3, with Windows 7 64-bit. SeaPro software by CIBRA (Pavan, 2017) was used for continuous long time recording on the notebook PC, this feature being very useful for those species with very faint sound emission and singing during nighttime.

Brizio & Buzzetti (2014) addressed in more detail some technical requirements of Ultramic 250 and proposed a specific operating protocol to ensure comparison between Ultramic recordings and audio range recordings available in literature.

Brizio (2015) described in more detail the challenges of ultrasound field recording and the requirements to obtain a recording as close as possible to the singing animal, to avoid the attenuation of faint high-order components. To ensure consistency with our previously published analyses, we applied the same methods here.

The first two Authors worked independently to collect the recordings to be used for the present work. When more recordings of a same subject or species were available, one of them was selected according to the following criteria:

- lowest disturbance from concurrent songs, wind and anthropogenic / technogenic noise;

- lowest distance between the microphone and the singing specimen, and thus better S/N ratio and highest number of feeble components recorded;

- appropriate gain setting of the microphone – in a general sense, among the three possible settings of Ultramic 250 (low, medium and high), medium gain provided the best results.

From the recordings of each species, several audio samples were selected and analyzed, choosing the clearest in the spectral structure of the song, that was analyzed and here illustrated and discussed. The position within the selected recordings, as well as the duration, of the selected audio samples were determined considering factors including:

- need to select a section unaffected, or minimally affected, by the disturbances cited above;

- nature of the song: trills, such as in *Ruspolia nitidula* and *Gryllotalpa gryllotalpa* may just require a selection of few syllables, while structured echemes with unequal syllables may require the selection of one or more full echemes (see below for terminology);

- interference by concurrent overlapping songs (either homo or heterospecific).

Field recordings face with real-world situations with the target songs often overlapped by environmental noise and/or by other songs. Concurrent songs occurred in several recording stations, and in some cases the resulting sound samples were unsuitable for a reliable analysis: in those cases, the species is not included in this paper (as in the case of *Euchorthippus declivus*, whose recording was inextricably overlapped by the songs of *Cicada orni* (Homoptera Cicadidae), or in the case of accidentally saturated recordings due to improper gain setting or unexpected level of the ultrasonic components). Whenever the concurrent songs did not overlap (for example, in the case of a background of far Gryllidae songs and a Tettigoniidae species in the foreground), as long as the lowest frequencies of the foreground songs where above the highest frequencies of the background songs, the frequency / level analysis window simply didn't include the band where interference by the heterospecific song was observed. In other cases of songs overlapping in the same frequency ranges, the echeme(s) used for the analysis were carefully selected by examining both the spectrogram and the envelope, to choose one or more echemes that didn't overlap. For example, this was the case of *T. tessellata*: in all the audio samples obtained, that included the concurrent song of up to four different species, only few echemes were deemed to fit for the analysis in several minutes of four different audio takes.

Even though we are perfectly aware of the poor frequency response of Ultramic 250 in the audible range, leading to waveforms that may slightly differ from those obtained by other types of microphone, we decided anyway to provide highly detailed waveforms and envelopes to facilitate comparisons with Ultramic recordings that other researchers may obtain.

Envelopes, spectrograms and frequency analysis plots were generated by Adobe Audition 1.0 software. Sound level is on an arbitrary scale, expressed in dB ref Full Scale Level. No real sound pressure level can be extrapolated. Spectrograms (normalized spectral energy) were generated with the following parameters: FFT and Window size 8192 samples, Windowing function Welch (Gaussian), logarithmic energy plot, sound level expressed in dB ref Full Scale Level.

Frequency analyses were made with the same parameters with Blackman-Harris windowing function.

The illustrations of frequency analyses were generated with a scan of the whole audio sample reported in Table 3. FFT-based analyses were performed on the sections shown in envelope or spectrogram views in two different ways:

- instantaneous (SPOT), on the time frame located at the current cursor position: although providing information at the smallest possible time scale, this may be useful e.g. to ascertain the emergence of different transient frequencies in different portion of the syllable; as a drawback, the instantaneous peaks of the analysis cannot necessarily match the features portrayed in the time-frequency spectrogram;

- by scanning (SCAN) a larger time frame, selected by dragging the cursor across the target piece of the envelope/spectrogram: in this way, all the sound elements in the selection are analyzed, thus providing a more general analysis, whose peaks more easily match the features in time-frequency spectrogram.

All the analyses provided, were obtained by scanning whole echemes or sequences of syllables.

The screenshots obtained from Adobe Audition were then post-produced with Adobe Photoshop Elements, by converting them in black and white and removing the background grid, and finally horizontal / vertical reference rulers were manually added with MS-Paint. Those intervention did not alter the data nor the analysis results.

It's well known (Welch et al., 2012; National Instruments Corporation, 2012) that the frequency resolution of FFT-based analyses is directly proportional to FFT size: higher FFT sizes lead to prickly frequency/level curves, lower sizes lead to smoother yet less precise depiction, but higher time resolution.

Considering the expected size of the pictures in this article and previous suggestions by reviewers of Brizio & Buzzetti 2014, we chose an FFT size of 8192 samples as an acceptable compromise between detail and smoothness of the picture.

To optimize the visualization and deliver optimal analyses, even though the whole 0-125 kHz frequency range was analyzed, the illustrations of analyses are limited to the frequency and level ranges where characteristic features, depending from the species, can be observed:

- the observation window of each spectral analysis was limited at the top by the highest level observed, and at the bottom by the highest level uniformly present at any frequency (that can be defined as "floor noise at any frequency");

- considering the frequency range, the recording bandwidth largely encompasses the range of frequencies emitted by the species; the upper limit in the figures was chosen to include, species by species, all the relevant components attributed to the singing animal.

The choice to optimize the frequency/level observation window for each species allowed us to exclude the noisy regions from the analyses, avoiding the noise peaks unless they overlapped the song.

Even though not particularly relevant, the noise of the AD converter may appear in the noise floor profile as a wide, ill-defined hump centered at around 50 kHz and extending between 40 and 60 kHz. This feature may become evident in the analyses of some recordings, such as those of Gryllidea where no wide-band components of the song overlap the same frequency interval.

Especially in urban areas or in the vicinity of high voltage transmission lines, Ultramic can record technogenic high frequency noise, such as continuous signals at 51 kHz or 61 kHz.

Where relevant, in the illustrations those spurious peaks are marked with a small circle.

In some analyses, the same mark above a narrow and well-defined peak indicates an artefact: narrow band noise, appearing in the spectrograms as thin, barely visible continuous lines at 1 kHz, 10 kHz or at some integer multiples of 1 kHz (such as 2, 3, 5 and 7 kHz), may be generated by Ultramic 250 as a side effect of the use of USB cables longer than 30 / 50 cm, as described in Brizio & Buzzetti, 2014. Species recorded with a longer USB cable are marked with an asterisk in Table 1.

Only in the case of *G. gryllotalpa*, a 18th order Butterworth band stop filter was successfully applied to the artefact peaks, encompassing the following frequencies: 990 Hz to 1010 Hz; 1990 Hz to 2010 Hz; 9990 Hz to 10010 Hz.

As a general rule no noise reduction was performed in post processing to avoid artefacts.

Table 2 summarizes the results of the analyses: a reference grid wasn't superposed on the figures provided in this paper because, considering their size, it would have hampered rather than facilitated their reading.

To give more evidence to the fainter significant spectral components, some of time/frequency spectrograms were contrast-enhanced with Adobe Photoshop Elements 4.0 without affecting the accuracy of rendering.

When describing songs, a useful distinction can be based on the quality factor Q, the dimensionless parameter that describes how underdamped an oscillator or resonator is. Two definitions of Q have prevailed in literature since its first appearance in 1914 (see Green, 1955). They become approximatively equivalent as Q becomes larger and damping decreases. In terms of frequency-to-bandwidth ratio, Q is defined as

$$Q \stackrel{\text{def}}{=} \frac{f_r}{\Delta f} = \frac{\omega_r}{\Delta \omega}$$

where fr is the resonant frequency, Δf is the resonance width or full width at half maximum (FWHM) i.e. the bandwidth over which the power of vibration is greater than half the power at the resonant frequency, $\omega r = 2\pi$ fr is the angular resonant frequency, and $\Delta\omega$ is the angular half-power bandwidth. The other common nearly equivalent definition for Q is the ratio of the energy stored in the oscillating resonator to the energy dissipated per cycle by damping processes:

$$Q \stackrel{\text{def}}{=} 2\pi \times \frac{\text{energy stored}}{\text{energy dissipated per cycle}} = 2\pi f_r \times \frac{\text{energy stored}}{\text{power loss}}$$

High-Q sound (Elsner & Popov 1978; Montealegre & Morris 1999) results in one or more (e.g. Gryllidae) isolated peaks of frequency, clearly distinguishable from the rest of the frequency emission. On the other hand, "wide band" or "low-Q" sound gives a wide band spectrogram traces, in which sometimes is possible to distinguish spectral subpeaks.

For what concerns audible sound description we use an array of terms from sources including Buzzetti & Barrientos (2011), Moore (1989) and Ragge & Reynolds (1998):

- Syllable (or phonatome): a short, clearly definable sound, produced by a complete opening and closing movements of the tegmina (or upward and downward movements of hind legs). In this case two subunits (hemisyllables) are clearly recognizable, usually characterized by pulses with opposite phases. In some cases the units are symmetrical, in other cases one of the sub units can be clearly different or barely visible, depending on the contact of the moving parts;

- Hemisyllable: distinct sound generated by each one-way movement of the stridulatory apparatus. A more loose definition may refer to any regularly recurring subdivision of a syllable;

- Zip: short syllable - the term may refer to short isolated pulses, as well as to the unitary elements in a quick series of pulses, that result in a short buzz;

- Trill: a long, regular series of uniform (equal or subequal), tightly packed syllables, dominated by a single frequency (Morris et al., 1988);

- Echeme: most basic and simple assemble of syllables.

To provide a general overview of the current knowledge of Italian Orthopterans in the inaudible range, Table 2 includes also the five Orthopteran species cited in our previous articles (Brizio & Buzzetti, 2014; Brizio, 2018).

Song descriptions and species distribution are excerpted from Cigliano et al., 2019 and Massa & al., 2012 - species are treated in the systematic order proposed by the latter monograph. Even though song description focuses on the subjective/perceptive aspect, rather than on technical and impersonal language, we consider that any doubt caused by the descriptive lexicon can be easily solved by reference to the figures, that provide no less than four, and often more, unambiguous illustrations for each species considered.

RESULTS AND DISCUSSION

Infraorder Gryllidea (general remarks). As expected from previous experiences and from bioacoustic literature, as a general rule Gryllidea emit high-Q song with a more or less pronounced harmonic structure. Our analyses confirmed that, while some species' song seems restricted to the lowest part of the inaudible range, the general rule applies also to the inaudible part of the song, with "harmonics" (integer multiples of the fundamental carrier frequency, in arithmetical progression) that in some cases, e.g. *G. gryllotalpa*, may be recognizable up to the 40th order or above.

Often, the dominant iterative harmonic structure coexists with secondary peaks or more or less pronounced wide bands, and may display selective amplification (e.g. the silenced 3rd harmonic of the marsh cricket *Pteronemobius concolor* usually fainter than the 4th) or obliteration of harmonics by secondary peaks or bands. In other words, the same phenomena determining the timbre and the color of audible sounds, selectively amplified or muffled by the vibrating structures of the tegmina (harp, chord, mirror and flexible region, see Montealegre et al., 2011), influence sound formation also in the inaudible region, where those complex interaction continue to occur, and where almost unexpectedly high order harmonics may reappear above apparently unstructured frequency bands.

In the case of the cricket *E. bordigalensis bordigalensis*, the analysis showed selective amplification and damping of some frequencies in the song of a specimen singing from under a manhole cover, with the cavity operating as a sound box. A second analysis of the species' typical song is provided, based on a specimen singing on open grassy ground. As expected, the differences observed confirm that closed cavities may significantly alter the spectral structure of the song, and in line of principle the analysis of such songs may lead to questionable results. It is also important to note that high frequencies are more directive than low frequencies and thus the recorded level of high components may also be influenced by the distance and orientation toward the microphone.

Other families (general remarks). For those families whose stridulatory apparatus lack structures, as those of Grylloidea, that preserve a good degree of spectral purity (Montealegre et al., 2011) or where those structures are much reduced, the inaudible portion of the song may consist in one or more repetition of ill-defined, more or less wide, frequency bands, with narrow or wide frequency peaks. Single peaks or whole bands may reappear at higher frequencies in a repetitive pattern, with a geometrical energy decrease proportional to the frequency.

In other cases the song may simply consist (especially in the case of "zips") in an uniform energy distribution: fading at frequency extremes, and covering the entire frequency range. In those cases, the song remains more or less unstructured throughout its full extension, and frequency analyses don't reveal any pattern except one or a few ill-defined bands.

Considering that in any Low-Q songs the narrow frequency peak corresponding to the highest volume may not coincide with the exact center of the loudest band, Table 2 includes two separate columns:

- For all the songs analyzed, "Peak Frequency", the exact frequency corresponding to the highest volume – its value is influenced by any parameter, such as FFT size, that affects frequency resolution;

- For the Low-Q songs only, "Low-Q main band center", the approximate frequency marking the graphical center of the loudest band - this more robust and more approximate value, less affected by FFT size, is provided to ease visual comparison with existing and future analyses obtained with different equipment and settings.

During our work, additional results - not described here - were obtained:

- novel discoveries emerged about *B. vicetinus* Galvagni et Fontana, 1993, *Anonconotus italoaustriacus* Nadig, 1987 and *Isophya modestior modestior* (Brunner von Wattenwyl, 1882), made possible by the analysis of their inaudible emissions: all those species show a previously unreported frequency shift among different syllables, between hemisyllables or among different parts of the echeme;

- it was confirmed that the different species of *Eupholidoptera* cannot be resolved on bioacoustic base only.

As stated above, this paper concentrates on a general description of the songs, and the novelties cited above will be the subject of separate future publications: further investigation may reveal whether sex-specific targeting of the different parts of each echeme, as reported e.g. for the amphibian *Eleutherodactylus coqui* Thomas, 1966 (Narins & al., 1976), is present also in Orthopterans.

Phaneroptera nana Fieber, 1853

DISTRIBUTION. Europe, Middle East and North Africa.

SONG DESCRIPTION. It sings mainly in the evening and the night. The song consists of series of irregularly repeated short sounds of different character. High-pitched clicks (syllables) are mixed with short "zb"-sounds (syllables). The latter resemble the sounds of *P. falcata*. Syllables seem never to be grouped in echemes.

ANALYSES. Band spectrum, mostly sonic, peak at 19830 Hz (Table 2, Fig. 1).

Tylopsis lilifolia (Fabricius, 1793)

DISTRIBUTION: from southern Europe and North Africa to Middle East.

SONG DESCRIPTION. The song consists of short groups of about 3 (1–5) short ticks (syllables). These groups are repeated with intervals about 10s up to more than a minute. The song is mainly produced during the day.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 23160 Hz (Table 2, Fig. 2).

Isophyia modestior modestior (Brunner, 1882)

DISTRIBUTION. Balkans and East Alps.

SONG DESCRIPTION. The song consists of sharp buzzing syllables of 150–200ms, repeated every 2–5s. A short and sharp tick at some distance follows many of these syllables. The song of specimens from Veneto seems different from the song of Serbian specimens, as described by Heller (1988). Further research in the ultrasonic range is necessary on Italian and Balkan populations.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 24890 Hz (Table 2, Fig. 3).

Barbitistes vicetinus Galvagni et Fontana, 1993

DISTRIBUTION. Italian endemic, the range being confined to the pre-alps of Veneto and Trentino.

SONG DESCRIPTION. The song is produced mainly in the evening and night. It consists of a sequence of quiet ticks (syllables), lasting for about 8–25s. Ticks are grouped in series of 10–25, with the exception of the last group, that usually only consists of 1–2 ticks. Sequences are separated by intervals of about 10s or more.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 24530 Hz (Table 2, Fig. 4).

Leptophyes laticauda (Frivaldszky, 1868)

DISTRIBUTION. Central-eastern Europe to the Balkans.

SONG DESCRIPTION. This species sings in the afternoon, evening and night. The song consists groups of 1–3 very faint ticks (syllables). Groups are repeated more or less regularly, at a minimum interval of about 1s. The faint song can hardly be heard with the unaided ear, but the species is easily traced with a bat detector, tuned at 20 kHz (ultrasonic).

ANALYSES. Band spectrum, mostly ultrasonic, peak at 31430 Hz (Table 2, Fig. 5).

Polysarcus denticauda (Charpentier, 1825)

DISTRIBUTION: from Central Europe to the Balkans.

SONG DESCRIPTION. It sings during the day and has a song with a characteristic sequence of different sounds. The first part of the song consists of a ticking/buzzing sound that can last for minutes. It merges into a more fast and high-pitched buzzing sound. This buzzing is suddenly followed by 1–3 loud ticks. After that the singing returns to the first part of the song. The male walks around when singing.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 26510 Hz (Table 2, Fig. 6).

Anisoptera fusca (Fabricius, 1793)

DISTRIBUTION. Widespread in the whole of Italy.

SONG DESCRIPTION. It mainly sings in the daytime. The song consists of a faint ticking/ rustling sequence, often lasting for minutes. The sequence is rarely interrupted by or ending with a more loose ticking sound for 0.5s or less.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 29020 Hz (Table 2, Fig. 7).

Ruspolia nitidula (Scopoli, 1786)

DISTRIBUTION. from Europe and North Africa to Central Asia.

SONG DESCRIPTION. The song is a continuous, very loud metallic buzz that can be heard in the night. The wings move very fast, and syllables are repeated at the rate of about 70–100/s.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 16290 Hz (Table 2, Fig. 8).

Tettigonia cantans (Fuessly, 1775)

DISTRIBUTION. From Central Europe to Central Asia.

SONG DESCRIPTION. This species starts singing in the afternoon and continues until late at night. In the daytime the song consists of an echeme of 1–5s, with a crescendo in the early part of each echeme. At high temperatures the song may sound sibilant, while at low temperatures in the evening it sounds vibrating and may last for more than one minute.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 8331 Hz (Table 2, Fig. 9).

Tettigonia viridissima (Linnaeus, 1758)

DISTRIBUTION. Palaearctic region.

SONG DESCRIPTION. As the congeneric *T. cantans*, this species sings in the afternoon, evening and night. The song is a very loud continuous rattling sound. Every element of the song (echeme) consists of two syllables that give a special quality to the rhythm of the song.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 41530 Hz (Table 2, Fig. 10).

Decticus albifrons (Fabricius, 1775)

DISTRIBUTION. From southern Europe and North Africa to south-western Asia.

SONG DESCRIPTION. This species sings during the day and in the evening. The song consists of sharp loud single ticks (syllables), with a certain resemblance to chirps of a bird. Ticks are repeated more or less regularly with a repetition rate between 2–10/s, typically about 5/s.

ANALYSES. composite spectrum, mostly ultrasonic, peak at 8300 Hz (Table 2, Fig. 11).

Decticus verrucivorus verrucivorus (Linnaeus, 1758)

DISTRIBUTION. From Europe to Siberia across Caucasus.

SONG DESCRIPTION. It has a loud song that is produced during the day. It consists of a sequence of sharp "zrrt"-sounds (echemes), often lasting for minutes. Characteristic is the increasing echeme repetition rate during a sequence, starting with isolated echemes, gradually increasing to about 10 echemes/s. Every echeme consists of four louder elements (syllables).

ANALYSES. Band spectrum, mostly ultrasonic, peak at 4660 Hz (Table 2, Fig. 12).

Platycleis affinis affinis (Fieber, 1853)

DISTRIBUTION. From Europe and North Africa to Central Asia.

SONG DESCRIPTION. It sings mainly in the afternoon and evening. The song is a faint echeme of variable duration (0.5–5s) that ends with a series of 2–9 short ticks (microsyllables). The first part of the echeme consists of macrosyllables, repeated at the rate of about 10–20/s.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 23800 Hz (Table 2, Fig. 13).

Tessellana tessellata tessellata (Charpentier, 1825)

DISTRIBUTION. From around the Mediterranean and Canary Is. to Caucasus.

SONG DESCRIPTION. It sings in the afternoon, evening and night. The song consists of a series of faint ticks (syllables), repeated irregularly at the rate of about 2/s, but sometimes regularly at the rate of about 7/s for a long period.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 31150 Hz (Table 2, Fig. 14).

Bicolorana bicolor bicolor (Philippi, 1830)

DISTRIBUTION. Species with Euro-Asiatic distribution, from France to Siberia and Mongolia.

SONG DESCRIPTION.This species mainly sings in the daytime. The song consists of a long sequence with a ticking/buzzing sound. Every element of the song (echeme) consists of three syllables that give a special quality to the rhythm of the song. Echemes are repeated at the rate of 15–25/s.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 21660 Hz (Table 2, Fig. 15).

Pholidoptera aptera aptera (Fabricius, 1793)

DISTRIBUTION. From Central Europe to the Balkans.

SONG DESCRIPTION. The song can be heard in the afternoon, evening and night. It consists of sequences of 5–40 short and loud, almost melodious "prri"-sounds (echemes). Sequences are repeated at intervals of about 5–10s and last for about 1–5s, but may last for 20s at low temperatures.

ANALYSES. Composite spectrum, mostly ultrasonic, peak at 25840 Hz (Table 2, Fig. 16).

Pholidoptera littoralis littoralis (Fieber, 1853)

DISTRIBUTION. From the Balkans to North-East Italy.

SONG DESCRIPTION. Its song can be heard in the afternoon and evening. It consists of a 1–4s long, loud and almost melodious "trrrri"-sound (echeme). The syllables are quiet in the first part of the echeme, but reach maximum intensity in the course of the echeme. Echemes are repeated at intervals of about 5–10s. There is some variability in the song of this taxon (Massa et al., 2012).

ANALYSES. Composite spectrum, mostly ultrasonic, peak at 25200 Hz (Table 2, Fig. 17).

Eupholidoptera chabrieri chabrieri (Charpentier, 1825)

DISTRIBUTION. From western and central Alps to northern Apennines and eastern France.

SONG DESCRIPTION.The song cannot be diagnostic in *Eupholidoptera*. Çiplak et al. (2009) have synonymized many Italian taxa. We retain here the original status of the Italian species and subspecies, awaiting more (molecular) research (see Allegrucci et al., 2013). This species sings both during the day and at night. The song consists of short "tsip"-sounds (syllable), that are at maximum repeated fairly regularly at the rate of about 0.5–2/s. The frequency spectrum shows a maximum at about 7–9 kHz. The song can hardly be distinguished from the song of other species of *Eupholidoptera*.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 38900 Hz (Table 2, Fig. 18).

Eupholidoptera schmidti (Fieber, 1861)

DISTRIBUTION. From northern Balkans, to North-East and Central Italy.

SONG DESCRIPTION. This species sings both during the day and at night. The song consists of short "tsip"-sounds (syllable), that are at maximum repeated fairly regularly at the rate of about 0.5–2/s. The frequency spectrum shows a maximum at about 7–9 kHz. The song can hardly be distinguished from the song of other species of *Eupholidoptera*.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 38290 Hz (Table 2, Fig. 19).

Eupholidoptera sp. (specimens recorded in the towns of Battaglia Terme and Chiampo)

ANALYSES. See Table 2 and figures 20, 21.

Anonconotus italoaustriacus (Nadig, 1987)

DISTRIBUTION. The genus *Anonconotus* is endemic of the Alps and the Apennines, this being the most eastern species in the Alps, occurring in Italy and Austria. It occupies a rather large range, but is quite scarce.

SONG DESCRIPTION. It sings in the afternoon, with a very faint rustling sound (echeme) of about 1–2.5s with about 24–55 syllables. Echemes are repeated irregularly at intervals of 5–30s. The song can be heard with bat detector, tuned at 30 kHz.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 36430 Hz (Table 2, Fig. 22).

Rhacocleis germanica (Herrich-Schäffer, 1840)

DISTRIBUTION. From southern Europe to the Balkans.

SONG DESCRIPTION. It mainly sings at night. The song consists of rustling/buzzing sounds (echemes) of 0.2–0.7s, repeated fairly regular at intervals of about 1–3s. The song can hardly be heard without bat detector, tuned at about 30kHz.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 28250 Hz (Table 2, Fig. 23).

Rhacocleis neglecta neglecta (Costa A., 1863)

DISTRIBUTION. From Italy to the North Balkans. Cited for Algeria in Cigliano et al., 2019.

SONG DESCRIPTION. The calling song is produced at night. It consists of an echeme of about 150-220ms ("zr"), repeated at the rate of 1–3/s in series 4s or longer. It consists of about 3–5 syllables, repeated at the rate of about 25/s.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 46690 Hz (Table 2, Fig. 24).

Antaxius difformis (Brunner, 1861)

DISTRIBUTION. Central European species, from Switzerland to Slovenia along the Alps.

SONG DESCRIPTION. It sings in the daytime, but also in the evening. The song consists of quiet rustling sounds (echeme sequences) of about 0.4s, repeated at intervals of about 1–3s. The echeme sequence has a variable and complex structure, but partly consists of paired syllables.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 27700 Hz (Table 2, Fig. 25).

Uromenus annae (Targioni-Tozzetti, 1881)

DISTRIBUTION. Endemic of Sardinia.

SONG DESCRIPTION. The male calling song (Fig. 30) consists of a series of syllables, with a repetition rate of 3.3 to 3.5 syllables/ sec. Each syllable lasts 0.278 sec (0.25–0.3, n=10). Main frequency between 11 and 32.5 kHz, with peak at 22.17 kHz (19.89–23.89, n=10).

ANALYSES. Band spectrum, mostly ultrasonic, peak at 24070 Hz (Table 2, Fig. 26).

REMARKS. This species was thought to be extinct while in the last decades few specimens from scattered populations have been collected. The Fondazione Museo Civico di Rovereto and the CNR of Sassari are running a joint research project on evaluation of the status of the populations and any conservation actions. This species has been the subject of a recent paper (Buzzetti et al., 2019)

Nemobius sylvestris sylvestris (Bosc, 1792)

DISTRIBUTION. West and South-central Europe.

Song description. It sings both in the daytime and during the night. The song consists of a series of quiet melodious, churring "prree"-sounds (echemes), repeated irregularly. Echemes can be very short, but can last up to 3s. In the presence of a female the male produces a courtship song with an alternation of periods with very short echemes and periods with very long echemes, lasting up to 5s.

Analyses. Composite spectrum, mostly sonic, peak at 3997 Hz (Table 2, Fig. 27). Specimen recorded with long USB cable (150 cm), artefact peaks are clearly marked in the frequency analysis.

Pteronemobius heydenii heydenii (Fischer, 1853)

Distribution. Europe and the Balkans.

Song description. It sings both in the daytime and during the night. The song consists of a series of quiet melodious, high-pitched churring "prree"-sounds (echemes) with a marked crescendo, lasting 1–4s and repeated at intervals of about 1–2s. Courtship song is unknown.

Analyses. High-Q spectrum, mostly sonic, peak at 7293 Hz, see also Tab. 2 and Fig. 28. Specimen recorded with long USB cable (150 cm), artefact peaks are clearly marked in the frequency analysis.

Gryllus bimaculatus (De Geer, 1773)

Distribution. Africa, Asia and Mediterranean Europe.

Song description. It sings especially during the night. The song consists of a series of loud melodious "kre"-sounds (echemes), repeated very regularly at the rate of about 1–4/s. All echemes in a series are equal, consisting of about 4–5 syllables. Males produce a courtship song in the vicinity of a female. It consists of a continuous rustling mixed with loud, high-pitched ticks.

Analyses. High-Q spectrum, mostly sonic, peak at 4913 Hz (Table 2, Fig. 29).

Gryllus campestris (Linnaeus, 1758)

Distribution. Europe, Western Asia and North Africa. Quite frequent in Italy, especially in the northern-central regions.

Song description. the song can be heard from May until August. It sings at daytime and during the night. The song consists of a series of loud melodious "kre"-sounds (echemes), repeated very regularly at the rate of about 1–4/s. All echemes in a series are equal, consisting of about 4 syllables, the first of which is usually emitted at a slightly lower volume. Males produce a courtship song in the vicinity of a female. It consists of a continuous rustling mixed with loud, high-pitched ticks.

Analyses. High-Q spectrum, mostly sonic, peak at 3723 Hz (Table 2, Fig. 30).

Remarks. two different analyses are provided, both from specimens recorded in the open at the same location and at the same temperature (16.3°C), to show that - despite a remarkable similarity in fundamental and main frequency peaks, different individuals may display, even to the unaided ear, significant timbre modification, with softer or sharper songs emitted in the same environmental conditions.

Brachytrupes megacephalus (Lefèvre, 1827)

Distribution. North Africa, Sicily, Sardinia.

Song description. It sings during the evening and night, usually just in front of its burrow, ready to flee inside at the slightest disturbance. The calling song is a continuous series of syllables repeated very fast (about 130/s). The peak frequency of the song is around 6kHz.

Analyses. High-Q spectrum, mostly sonic, peak at 5920 Hz (Table 2, Fig. 31).

Remarks. This is the biggest European cricket and as reported by Brizio (2018) it has a high-order harmonic structure. Given the rarity of this species, the song detection could be useful in adding new distribution data. This could be important, being a species included in the Habitat Directive.

Eumodicogryllus bordigalensis bordigalensis (Latreille, 1804)

DISTRIBUTION. Mediterranean Region.

SONG DESCRIPTION. It sings in the evening and during the night. The song consists of a series of loud melodious, rolling krrree-sounds (echemes), repeated regularly at the rate of about 2–4/s. The echemes consist of about 14–20 syllables. A courtship song is unknown.

ANALYSES. High-Q spectrum, mostly sonic peak at 5737 Hz (Table 2, Fig. 32).

Oecanthus pellucens pellucens (Scopoli, 1763)

DISTRIBUTION. From Europe and North Africa to Central Asia, across Arabian Peninsula and Caucasus.

SONG DESCRIPTION. It sings in the evening and at night. This is the cricket song of warm summer evenings. The song consists of a series of loud melodious "tree"-sounds (echemes), lasting 0.5–1s and repeated very regularly at the rate of about 0.5–2/s. All echemes in a series are equal, consisting of about 15–30 syllables.

ANALYSES. High-Q spectrum, mostly sonic, peak at 3479 Hz (see also Table 2, Fig. 33).

REMARKS. For the song comparison with the congeneric *O. dulcisonans*, see Brizio & Buzzetti (2014), the ecology of the two spp. in southern Italy is discussed in Labadessa & Todisco (2016). Data in Table 2 are based on new recordings in the same station of the 2014 paper, taken in July 2019 under more favorable conditions, and displaying a more complex harmonic structure than previously reported.

Gryllotalpa gryllotalpa (Linnaeus, 1758)

DISTRIBUTION. From Europe and North Africa to Middle Asia.

SONG DESCRIPTION. The song consists of a continuous loud melodious rattle (echeme). Syllables are repeated regularly at the rate of about 30–50/s.

ANALYSES. High-Q spectrum, mostly sonic, peak at 1434 Hz (Table 2, Fig. 34).

Euthystira brachyptera (Ocskay, 1826)

DISTRIBUTION. From Europe to Asia.

SONG DESCRIPTION. It sings in the daytime. The song consists of high pitched short quiet sounds (echemes), consisting of about 4–7 syllables. Echemes are repeated more or less regularly at minimum intervals of about 2–4s.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 29050 Hz (Table 2, Fig. 35).

Chorthippus (Chorthippus) dorsatus dorsatus (Zetterstedt, 1821)

DISTRIBUTION. Widely distributed from Europe to Siberia.

SONG DESCRIPTION. *C. dorsatus dorsatus* sings by day. The song consists of a series of short scratching/rustling sounds (echemes) lasting about 0.8–1.5s and repeated regularly at intervals of about 1–3s. The echeme consists of about 3–7 clear scratching syllables, followed by a short rustling sound. In situations of social interaction of two males (rivalry) the rustling part of the song remains, while the scratching syllables are left out.

ANALYSES. Band spectrum, mostly ultrasonic, peak at 22790 Hz (Table 2, Fig. 36).

Chorthippus (Chorthippus) parallelus parallelus (Zetterstedt, 1821)

DISTRIBUTION. From Europe to Siberia.

SONG DESCRIPTION. It sings by day, but might easily be heard during warm evenings. The song consists of a series of short scratching sounds (echemes) lasting about 1–2s and repeated regularly at intervals of about 3–5s. The echeme consists of about 10–20 clear scratching syllables, repeated at the rate of about 4–6/s. In situations of social interaction of two males (rivalry) the echemes are shortened and sound different, more rustling, like *C. d. dorsatus* or *C. dichrous*.

ANALYSES. Composite spectrum, mostly ultrasonic, peak at 29930 Hz (Table 2, Fig. 37).

N.	Sub-family	Species	Rec. Date/Time yyyymmdd-hhmmss	Recording locality	Lat-Long	Specimen observed
1	PHA	*Phaneroptera nana* Fieber, 1853	20140822-212018	Poggio Renatico	44.762,11.475	Yes
2	PHA	*Tylopsis lilifolia* (Fabricius,1793)	20150726-210335	Bologna, Parco Villa Ghigi	44.475,11.325	Yes
3	PHA	*Isophya m. modestior* (Brunner, 1882)	20180818-203000	Passo Croce d'Aune	46.052,11.841	Yes
4	PHA	*Barbitistes vicetinus* Galvagni & Fontana,1993	20130629-212429	Via S.G. in M.te,Colli Berici	45.442,11.563	Yes
5	PHA	*Leptophyes laticauda* (Frivaldszky,1868)	20120808-210041	Madonna dell'Acero	44.148,10.821	Yes
6	PHA	*Polysarcus denticauda* (Charpentier, 1825)	20130907-(unav.)	PNDB Vette Feltrine	46.093,11.844	Yes
7	CON	*Anisoptera fusca* (Fabricius, 1793)	20180725-191748	Marina Romea	44.524,12.269	No
8	CON	*Ruspolia nitidula* (Scopoli,1786)	20120729-001551	Poggio Renatico	44.762,11.475	Yes
9	TET	*Tettigonia cantans* (Fuessly,1775)	20120807-182648	Madonna dell'Acero	44.148,10.821	Yes
10	TET	*Tettigonia viridissima* (Linnaeus,1758)	20130629-212525 20120807-230257 20130829-223308	Colli Berici, Tr. Vecia Priara Madonna dell'Acero Sardegna, Fluminimaggiore	39.447,08.461 44.148,10.821 45.454,11.556	Yes
11	TET	*Decticus albifrons* (Fabricius,1775)	20120718-105942	Ferrara	44.809,11.597	Yes
12	TET	*Decticus v. verrucivorus* (Linnaeus,1758)	20120813-124321	Madonna dell'Acero	44.148,10.821	Yes
13	TET	*Platycleis a. affinis* Fieber, 1853	20180725-212909	Marina Romea	44.499,12.283	No
14	TET	*Tessellana t. tessellata* (Charpentier,1825)	20150726-210335	Bologna, Parco Villa Ghigi	44.475,11.325	Yes
15	TET	*Bicolorana b. bicolor* (Philippi, 1830)	20120813-130104 20180813-(unav.)	Madonna dell'Acero PNDB Monte Grave	44.148,10.821 46.089,11.928	Yes
16	TET	*Pholidoptera a. aptera* (Fabricius,1793)	20130713-214504 20130629-212429	Madonna dell'Acero Colli Berici	44.148,10.821 45.442,11.563	No
17	TET	*Pholidoptera l. littoralis* (Fieber, 1853)	20180618-(unav.)	Colli Berici, Pianezze	45.486,11.559	Yes
18	TET	*Eupholidoptera c. chabrieri* (Charpentier, 1825)	20151024 141824	Passo della Raticosa	44.195,11.358	Yes
19	TET	*Eupholidoptera schmidti* (Fieber,1861)	20120717-225522	Poggio Renatico	44.762,11.475	Yes
20	TET	*Eupholidoptera* sp. Battaglia	20180618-2015	Colli Euganei, Battaglia	45.292,11.773	Yes
21	TET	*Eupholidoptera* sp. Chiampo	20180713-1942	Chiampo	45.534,11.306	Yes
22	TET	*Anonconotus italoaustriacus* Nadig,1987	20130816-082000	PNDB Vette Feltrine	46.093,11.844	Yes
23	TET	*Rhacocleis germanica* (Herrich-Schäffer,1840)	20150726-204011	Marina Romea	44.475,11.325	Yes
24	TET	*Rhacocleis n. neglecta* (Costa & A.,1863)	20151024-141824	Passo della Raticosa	44.195,11.358	No
25	TET	*Anthaxius difformis* (Brunner, 1861)	20130910-(unav.)	PNDB Vette Feltrine	46.075,11.842	Yes
26	BRA	*Uromenus annae* (Targioni-Tozzetti,1881)	20180801-235237	Crastazza, Mamone	40.586,09.410	Yes
27	NEM	*Nemobius s. sylvestris* (Bosc, 1792) *	20180722-141134	M.te Pigna,S. Lucia,Vergato	44.308,11.037	No
28	NEM	*Pteronemobius h. heydenii* (Fischer,1853)*	20150726-210335	San Pietro in Casale	44.675,11.422	No
29	GRY	*Gryllus bimaculatus* De Geer, 1773	20150825-121424	Cala Domestica	39.373,08.379	No
30	GRY	*Gryllus campestris* Linnaeus, 1758	20190427-225055	Gherghenzano	44.676,11.382	No
31	GRY	*Brachytrupes megacephalus* (Lefèvre, 1827)	20180422-205622	Capo Pecora, Sardinia	39.450,08.396	Yes
32	GRY	*Eumodicogryllus b. bordigalensis* (Latreille,1804)	20180728-220303	Poggio Renatico	44.762,11.475	No
33	OEC	*Oecanthus p. pellucens* (Scopoli, 1763)	20180802-010021	S.Benedetto, S. Pietro in C.	44.697,11.376	Yes
34	GTL	*Gryllotalpa gryllotalpa* (Linnaeus,1758)*	20180529-235220	San Pietro in Casale	44.681,11.439	No
35	GOM	*Euthystira brachyptera* (Ocskay, 1826)	20180813-143000	PNDB Monte Grave	46.085,11.934	Yes
36	GOM	*Chorthippus (C.) d. dorsatus* (Zetterstedt,1821)	20140817-(unav.)	Castelcerino (VR)	45.462,11.241	Yes
37	GOM	*Chorthippus (C.) p. parallelus* (Zetterstedt,1821)	20120812-174718	Madonna dell'Acero	44.148,10.821	Yes

Table 1. Comprehensive list of the species exained and recording localities (all in Italy). Exact hour/minute of recording could not be ascertained in the sases marked with (unav.). Subfamily legend: PHA: Tettigoniidae Phaneropterinae. CON: Tettigoniidae Conocephaline. TET: Tettigoniidae Tettigoniinae. BRA: Tettigoniidae Bradyporinae. NEM: Gryllidae Nemobiinae. GRY: Gryllidae Gryllinae. OEC: Gryllidae Oecanthionae. GTL: Gryllotalpidae Gryllotalpinae. GOM: Acrididae Gomphocerinae. *USB cable length = 150 cm (30 or 50 cm in all the other case).

Family Subfamily	Species	Spectrum type	Most relevant emission	Recording distance cm (*)	Peak frequency Hz	Low-Q main band center kHz	Highest kHz emitted	Highest harmonic (High-Q)
Tettigoniidae Phaneropterinae	*P. nana*	Band	sonic	200	19830	20	45	n/a
	T. lilifolia	Band	ultrasonic	400	23160	25	80	n/a
	I. m. modestior	Band	ultrasonic	30	24890	24	75	n/a
	B. vicetinus	Band	ultrasonic	50	24530	24	60	n/a
	L. laticauda	Band	ultrasonic	100	31430	31	55	n/a
	P. denticauda	Band	ultrasonic	50	26510	24	70	n/a
Tettigoniidae Conocephalinae	*A. fusca*	Band	ultrasonic	100	29020	29	100	n/a
	R. nitidula	Band	ultrasonic	400	16290	15	75	n/a
Tettigoniidae Tettigoninae	*T. cantans*	Band	ultrasonic	50	8331	9	70	n/a
	T. viridissima	Band	ultrasonic	100	41530	40	90	n/a
	D. albifrons	composite	ultrasonic	300	8300	38	85	7 - 8
	D. v. verrucivorus	Band	ultrasonic	200	4.660	44	85	n/a
	P. a. affinis	Band	ultrasonic	200	23800	27	110	n/a
	T. t. tessellata	Band	ultrasonic	250	31150	33	85	n/a
	B. b .bicolor	Band	ultrasonic	100	21660	22	85	n/a
	P. a. aptera	composite	ultrasonic	100	25840	28	75?	n/a
	P. l. littoralis	composite	ultrasonic	50	25200	35	80	12
	E. c. chabrieri	Band	ultrasonic	300	38900	35	90	n/a
	E. schmidti	Band	ultrasonic	50	38290	44	75	n/a
	Eupholidoptera sp. (Euganei Battaglia)	Band	ultrasonic	50	21540	35	85	n/a
	Eupholidoptera sp. (Chiampo)	Band	ultrasonic	50	39090	40	85	n/a
	A. italoaustriacus	Band	ultrasonic	30	36430	45	80	n/a
	R. baccettii (a)	Band	ultrasonic	200	51000	28	105	n/a
	R. germanica	Band	ultrasonic	150	28250	27	85	n/a
	R. n. neglecta	Band	ultrasonic	250	46690	46	90	n/a
	A. difformis	Band	ultrasonic	50	27700	28	65	n/a
Tettigoniidae Bradyporinae	*U. annae*	Band	ultrasonic	50	24070	22	65	n/a
	U. brevicollis insularis (a)	Band	sonic	200	13450	12	41	n/a
Gryllidae Nemobiinae	*N. s. sylvestris*	composite	sonic	50	3.997	n/a	60	3
	P. h. heydenii	High-Q	sonic	100	7.293	n/a	50	6
Gryllidae Gryllinae	*G. bimaculatus*	High-Q	sonic	100	4.913	n/a	60	11
	G. campestris	High-Q	sonic	80	3.723	n/a	70	19
	B. megacephalus (b)	High-Q	sonic	50	5.920	n/a	121.7	21
	S. p. palmetorum (a)	High-Q	sonic	20	6.317	n/a	32	5
	E. b. bordigalensis	High-Q	sonic	30 / 100	5.737	n/a	45	6 - 8
Gryllidae Oecanthinae	*O. dulcisonans* (a)	High-Q	sonic	50	2.960	n/a	44.7	15
	O. p. pellucens	High-Q	sonic	10	3.479	n/a	65	18
Gryllotalpidae	*G. gryllotalpa*	High-Q	sonic	20	1.434	n/a	55	38
Acrididae Gomphocerinae	*E. brachyptera*	Band	ultrasonic	50	29050	29	60	n/a
	C. (C.) d. dorsatus	Band	ultrasonic	50	22790	25	65	n/a
	C. (C.) p. parallelus	composite	ultrasonic	50	29930	28	65	n/a

Table 2. Synopsis of the ultrasound components of the species examined. Shaded lines mark species treated in separate papers: a) *O. dulcisonans*, *R. baccettii*, *S. p. palmetorum*, and *U. b. insularis* from Brizio & Buzzetti, 2014, integrated by recordings in July 2019 (*O. dulcisonans*) and August 2019 (*R. baccettii*), b) *Brachytrupes megacephalus*, data from Brizio, 2018. (*) Approximate distance between the microphone and the singing insect during recording.

Sub-family	Species	Audio File Name	Analyzed section (Min:sec.msec)			Highest kHz emitted
			From	To	Length	
PHA	*Phaneroptera nana*	Phaneroptera nana Poggio_20140822 212018.wav	1:04.527	1:22.035	17.508	45
PHA	*Tylopsis lilifolia*	Tylopsis Lilifolia estratto zip non saturi VillaGhigi_20150726 210335.wav	0	0.201	0.201	80
PHA	*Isophya m. modestior*	Isophya modestior e Poecilimon ornatus SeaPro PNDB Passo Croce d'Aune july18_MONO.wav	2:35.732	2:50.800	15.068	75
PHA	*Barbitistes vicetinus*	Barbitistes vicetinus Euganei Madonna Pholidoptera littoralis Berici Pianezze june18.wav	12.496	14.195	1.698	60
PHA	*Leptophyes laticauda*	Leptophyes_laticauda_Madonna_Acero_Pattern_1_5_MedGain_20120808_204915_1CH250K16.wav	1:35.729	1:44.308	8.579	55
PHA	*Polysarcus denticauda*	Polysarcus denticauda Vette Feltrine 7sept2013.wav	48.404	51.464	3.06	70
CON	*Anisoptera fusca*	*Anisoptera_fuscus*_sinonimo_*Xiphidion_discolor*_FORSE_Marina_Romea_20180725 191748.wav	2:04.662	2:19.077	14.414	100
CON	*Ruspolia nitidula*	Ruspolia_nitidula_Circonvallazione_Poggiorenatico_20120729_001732_1CH250K16.wav	4.091	6.335	2.244	75
TET	*Tettigonia cantans*	Tettigonia_cantans_Madonna_Acero_MedGain_20120807_182648_1CH250K16.wav	1:32.769	1:37.030	4.261	70
TET	*Tettigonia viridissima*	Tettigonia_viridissima_Madonna_Acero_MedGain_20120807_230257_1CH250K16.wav	15.533	21.818	6.284	90
TET	*Decticus albifrons*	Decticus_albifrons_RedTurtle_ok_SeaPro_20120718_105942_1CH250K16.wav	21.556	22.457	0.901	85
TET	*Decticus v. verrucivorus*	Decticus_verrucivorus_Madonna_Acero_20120813_124321_1CH250K16.wav	1:34.011	1:37.791	3.779	85
TET	*Platycleis a. affinis*	Platycleis_affinis_affinis_MIGLIORE_Marina_Romea_20180725 212909.wav	1.475	5.558	4.082	115
TET	*Tessellana t. tessellata*	ESTRATTO R_germanica_T_tessellata_T_lilifolia VillaGhigi_20150726 211922.wav	18.632	18.724	0.096	85
TET	*Bicolorana b. bicolor*	Bicolorana_bicolor_Madonna_Acero_LoGain_20120813_130104_1CH250K16.wav	1:21.937	1:28.075	6.138	85
TET	*Pholidoptera a. aptera*	Pholidoptera aptera aptera_Madonna_Acero_canone SeaWave _20130713 214504.wav	1:30.979	1:43.153	12.173	65
TET	*Pholidoptera l. littoralis*	Same track as *B. vicetinus*	32.036	34.668	2.632	80
TET	*Eupholidoptera c. chabrieri*	Eupholidoptera chabrieri Raticosa _20151024 144136.wav	22.85	26.022	3.172	90
TET	*Eupholidoptera schmidti*	Eupholidoptera_schmidti_Via_Chiesavecchia_45_Poggio_ok_SeaPro_20120717_225522_1CH250K16.wav	6.13	9.56	3.43	75
TET	*Eupholidoptera* Euganei Battaglia	Eupholidoptera Euganei Battaglia june18	38.927	56.788	17.86	85
TET	*Eupholidoptera* Chiampo	Eupholidoptera Chiampo july13.wav	18.433	21.521	3.087	85
TET	*Anonconotus italoaustriacus*	Anonconotus italoaustriacus Vette Feltrine 16aug2013.wav	1:25.618	1:25.747	0.129	80
TET	*Rhacocleis germanica*	Rhacocleis_germanica_Forse_Marina_Romea_20180725 211926.wav	8.997	9.303	0.306	85
TET	*Rhacocleis n. neglecta*	Rhacocleis neglecta neglecta Raticosa _20151024 142110.wav	6.543	7.16	0.616	90
TET	*Antaxius difformis*	Antaxiusdifformis _20130910_PNDBVetteFeltrineFMB.wav	25.467	26.612	1.145	65
BRA	*Uromenus annae*	Steropleurus annae Crastazza high gain SeaPro_20180801_235237_1CH250K16 (2).wav	22.764	24.725	1.96	65
NEM	*Nemobius s. sylvestris*	Nemobius sylvestris _20180722 141134.wav	17.492	26.025	8.532	65
NEM	*Pteronemobius h. heydenii*	Pteronemobius_concolor_San_Pietro_in_Casale_20180530 001328.wav	6.511	14.951	8.439	50
GRY	*Gryllus bimaculatus*	Gryllus bimaculatus Cala Domestica - SeaWave _20150825 123153.wav	1.66	2.1	0.439	60
GRY	*Gryllus campestris*	Gryllus_campestris_Gherghenzano_SeaWave _20190427 225055	36.493	41.417	4.942	71
GRY	*Gryllus campestris*	Gryllus_campestris_Gherghenzano_SeaWave _20190427 230303	22.181	26.900	4.719	60
GRY	*Brachytrupes megacephalus*	B_megacephalus_C_Pecora_20180422-205622.wav	16.869	19.873	3.003	100
GRY	*Eumodicogryllus b. bordigalensis*	Eumodicogryllus_burdigalensis_PoggioRenatico_20180724 013359.wav	13.057	17.628	4.571	45
OEC	*Oecanthus p. pellucens*	Oecanthus_pellucens_San_Benedetto_20180802 010021.wav	12.86	13.438	0.578	
GTL	*Gryllotalpa gryllotalpa*	Gryllotalpa_gryllotalpa_San_Pietro_in_Casale_20180529 235619.wav	43.073	46.575	3.501	55
GOM	*Euthystira brachyptera*	Euthystira brachyptera Monte Grave PNDB.wav	1:24.675	1:36.358	11.683	60
GOM	*Chorthippus (C.) d. dorsatus*	Chorthippus dorsatus Castelcerino 17aug14FMB.wav	54.337	54.838	0.501	65
GOM	*Chorthippus (C.) p. parallelus*	Chorthippus_parallelus_Madonna_Acero_LoGain_20120812_174718_1CH250K16.wav	1:28.591	1:43.417	14.825	65

Table 3. Details about the audio samples used for the frequency analyses. Subfamily legend: see Table 1.

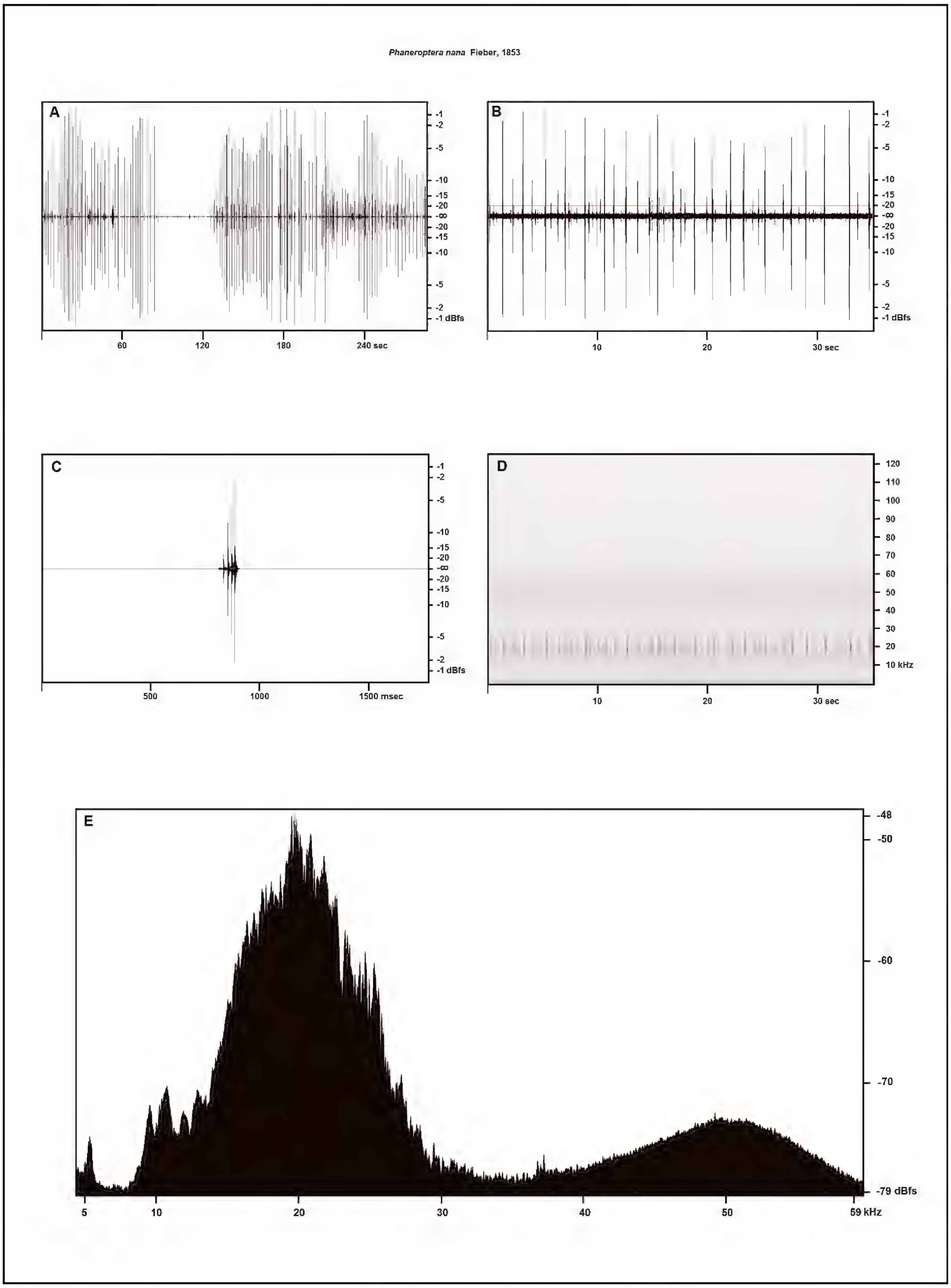


Figure 1. *Phaneroptera nana* Fieber, 1853 – A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 17.508 sec (see Table 3). The components between 40 and 60 kHz are due to the noise of the AD converter, that is visible in other figures.

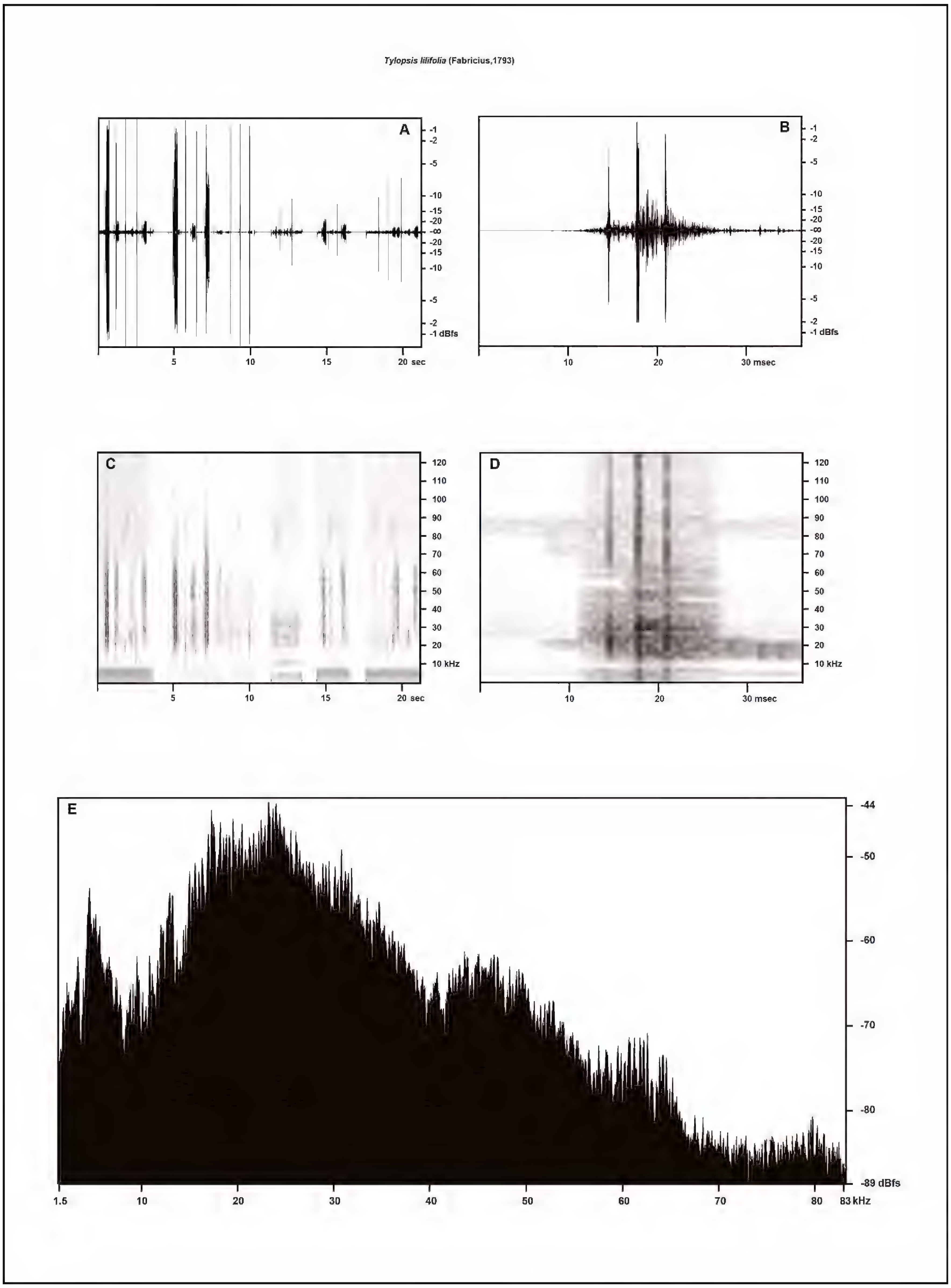


Figure 2. *Tylopsis lilifolia* (Fabricius,1793) - A, B: envelope at two increasing levels of detail, A, C, D: spectrogram at two increasing levels of detail, E: frequency analysis - 0.201 sec (see Table 3).

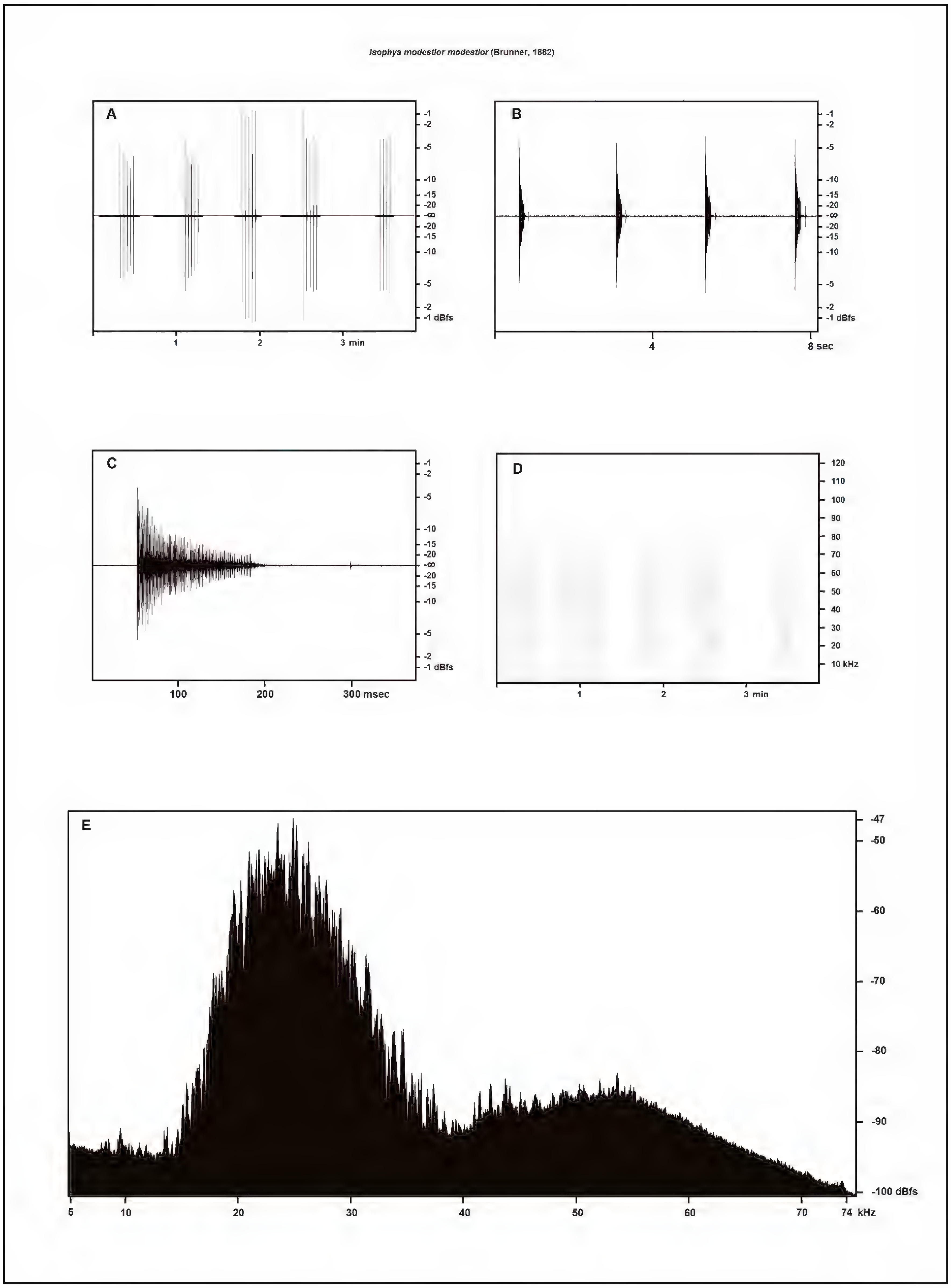


Figure 3. *Isophya modestior modestior* (Brunner, 1882) - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 15.068 sec (see Table 3).

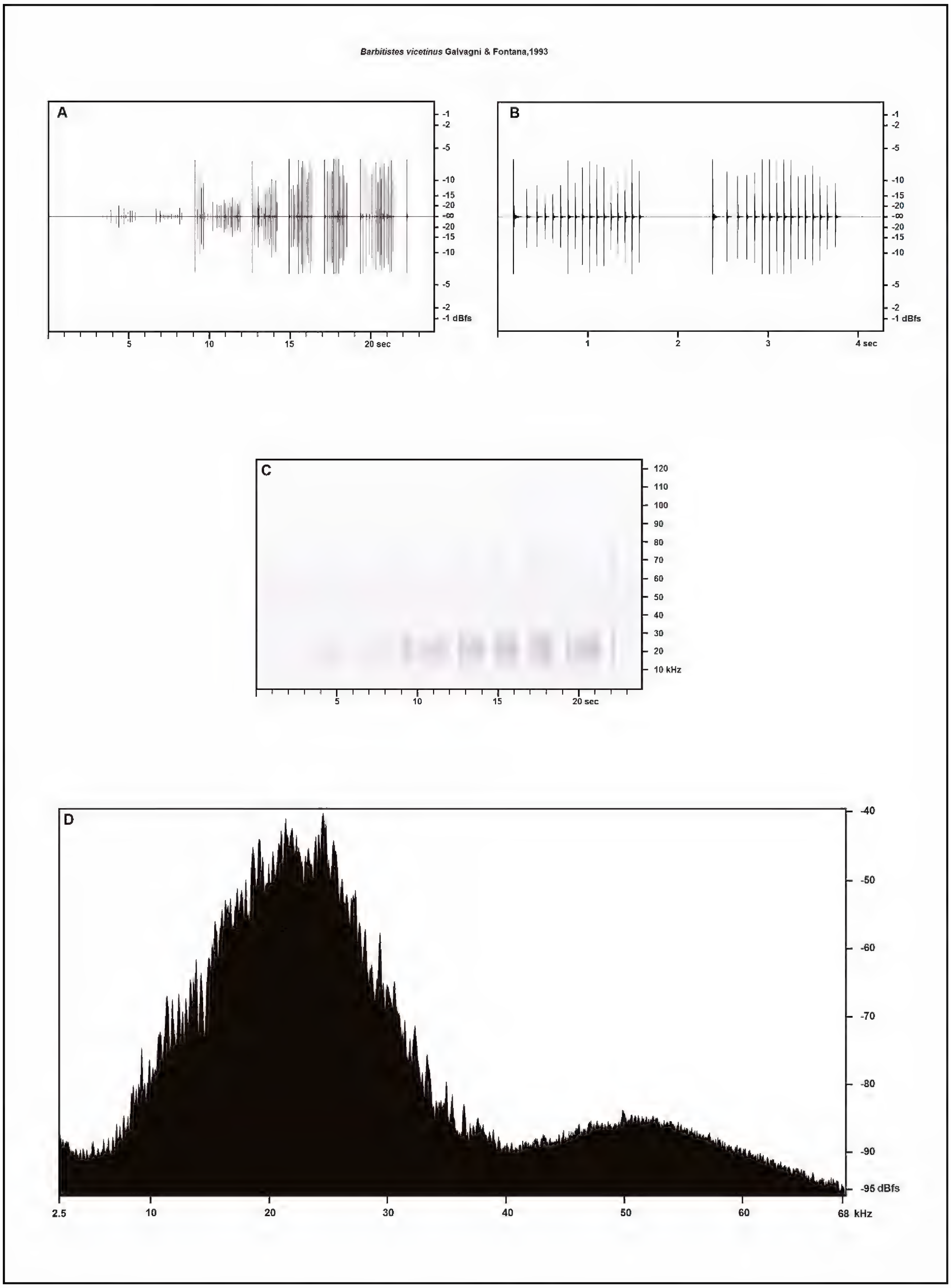


Figure 4. *Barbitistes vicetinus* Galvagni & Fontana,1993 - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 1.698 sec (see Table 3).

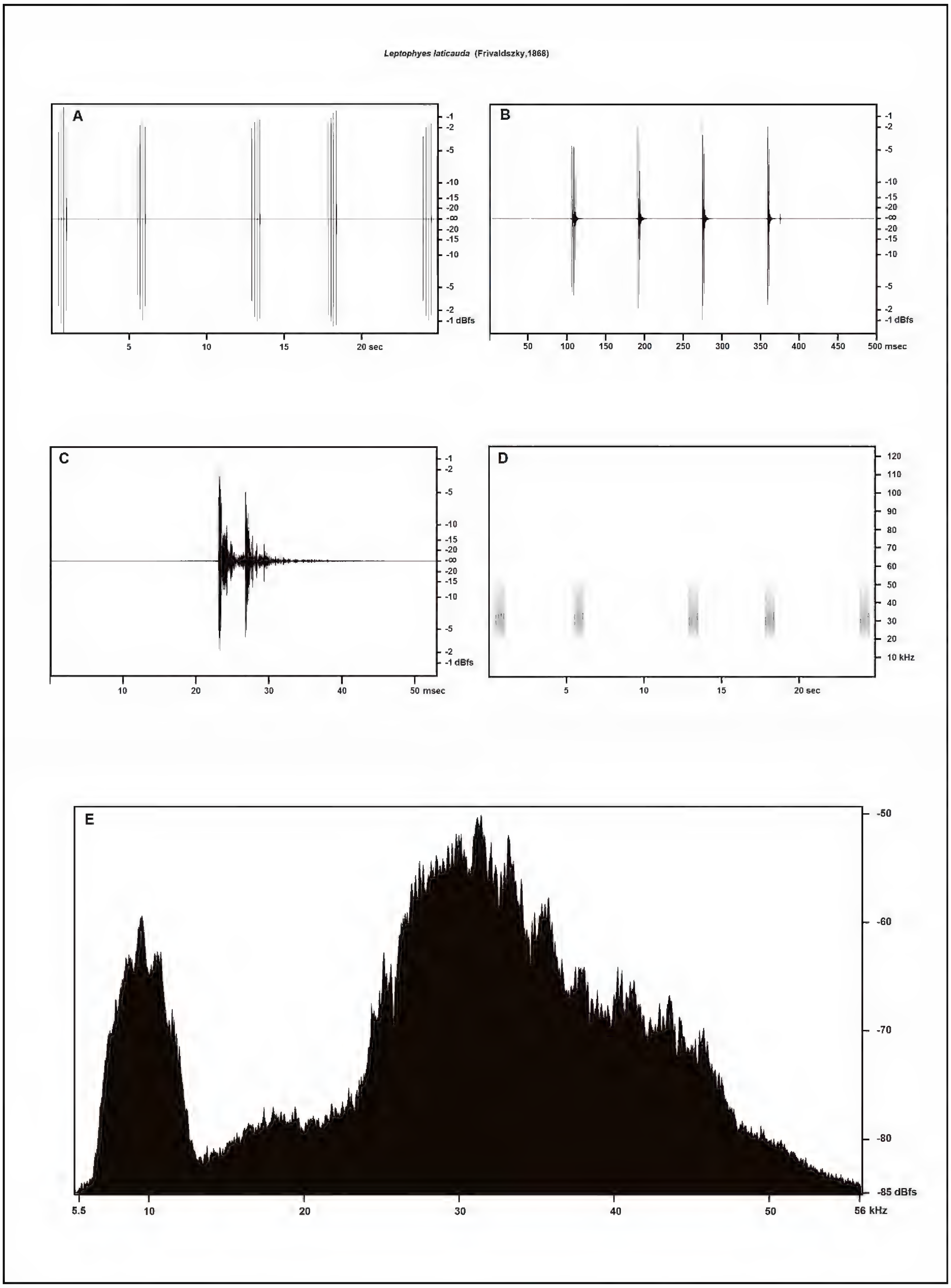


Figure 5. *Leptophyes laticauda* (Frivaldszky,1868) - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 8.579 sec (see Table 3).

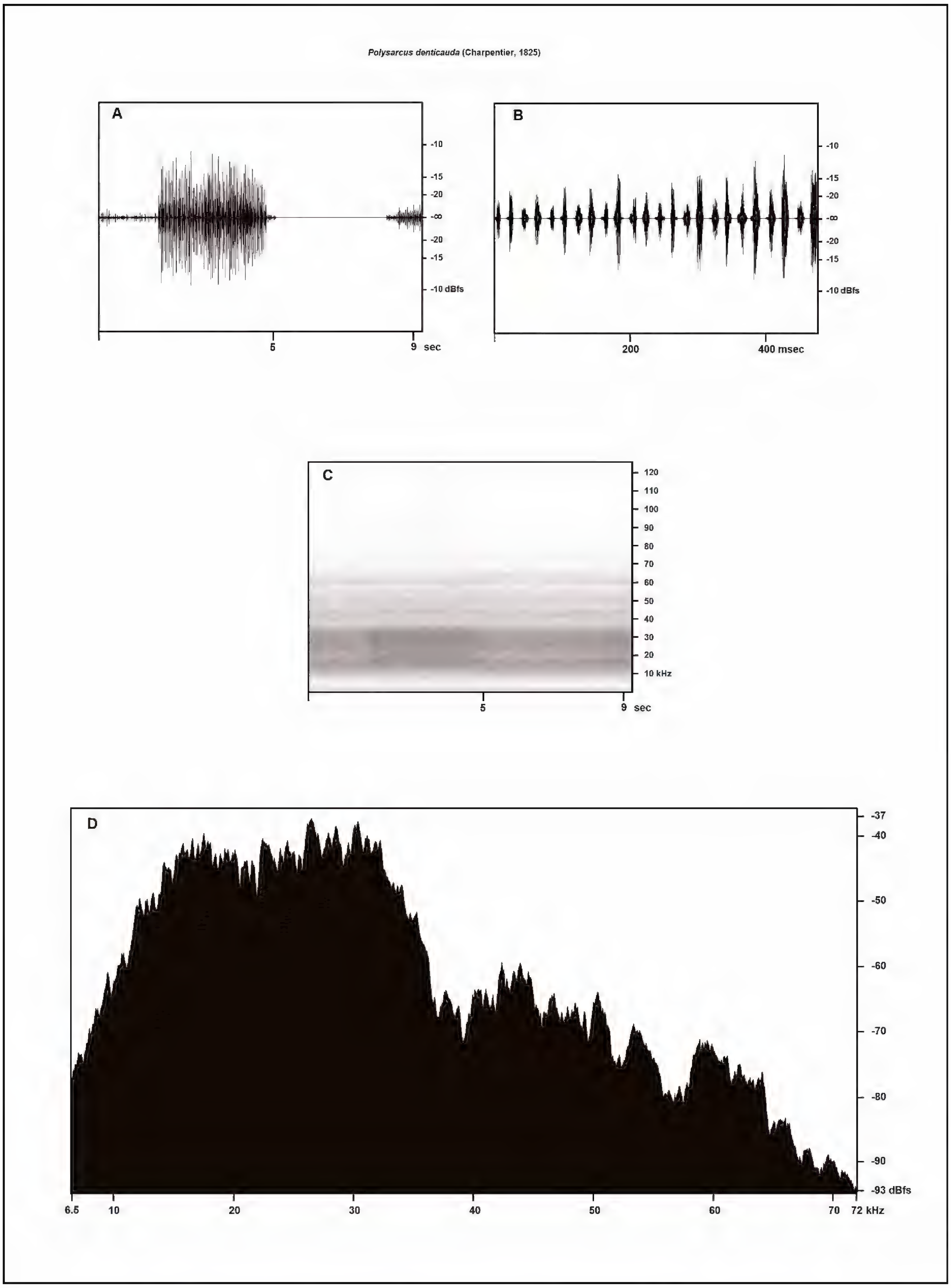


Figure 6. *Polysarcus denticauda* (Charpentier, 1825) - A, B: envelope in three increasing levels of detail, C: spectrogram, D: frequency analysis - 3.060 sec (see Table 3).

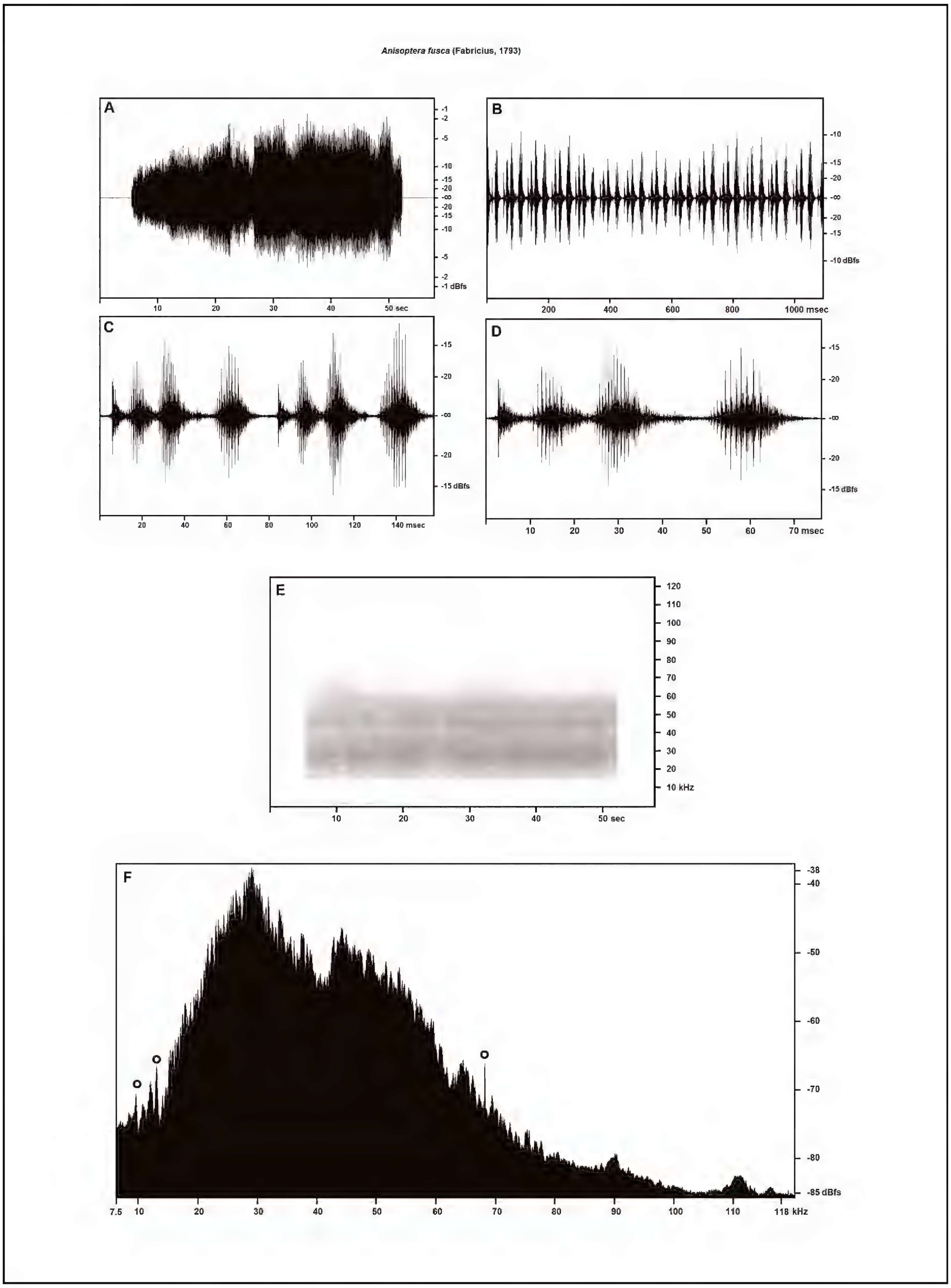


Figure 7. *Anisoptera fusca* (Fabricius, 1793) - A, B, C, D: envelope in four increasing levels of detail, E: spectrogram, F: frequency analysis - 14.414 sec (see Table 3).

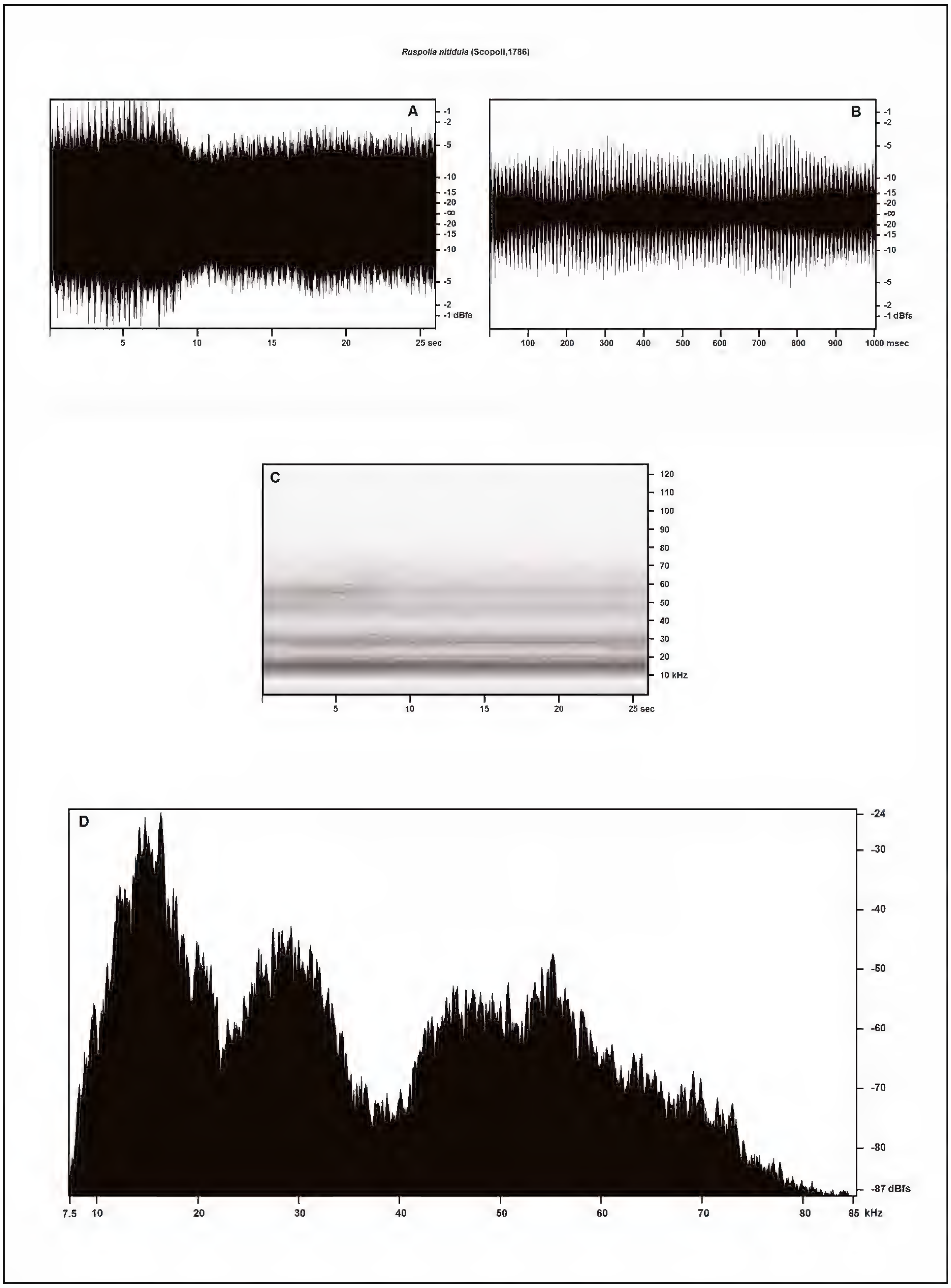


Figure 8. *Ruspolia nitidula* (Scopoli,1786) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 2.244 sec (see Table 3).

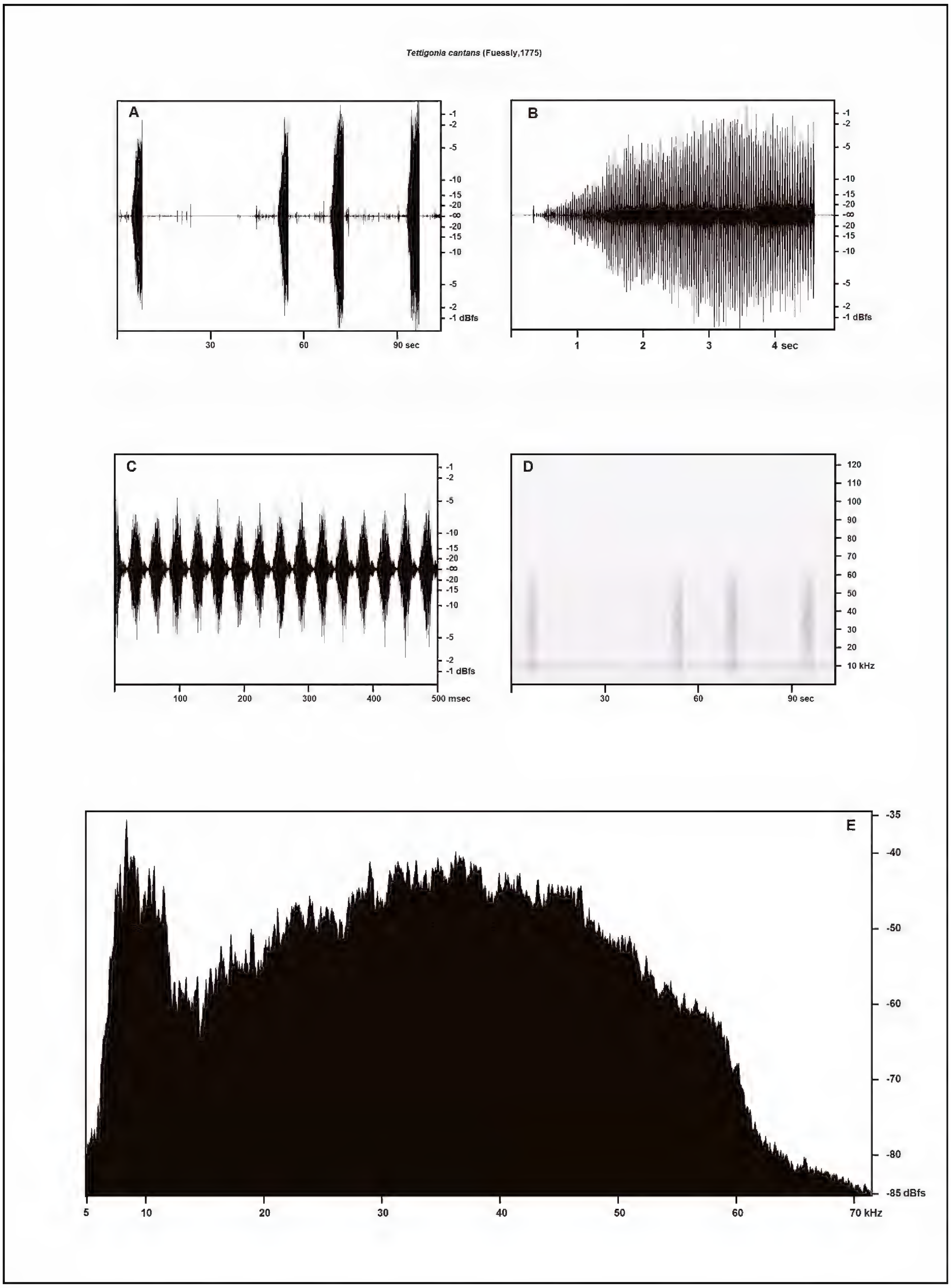


Figure 9. *Tettigonia cantans* (Fuessly,1775) - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 4.261 sec (see Table 3).

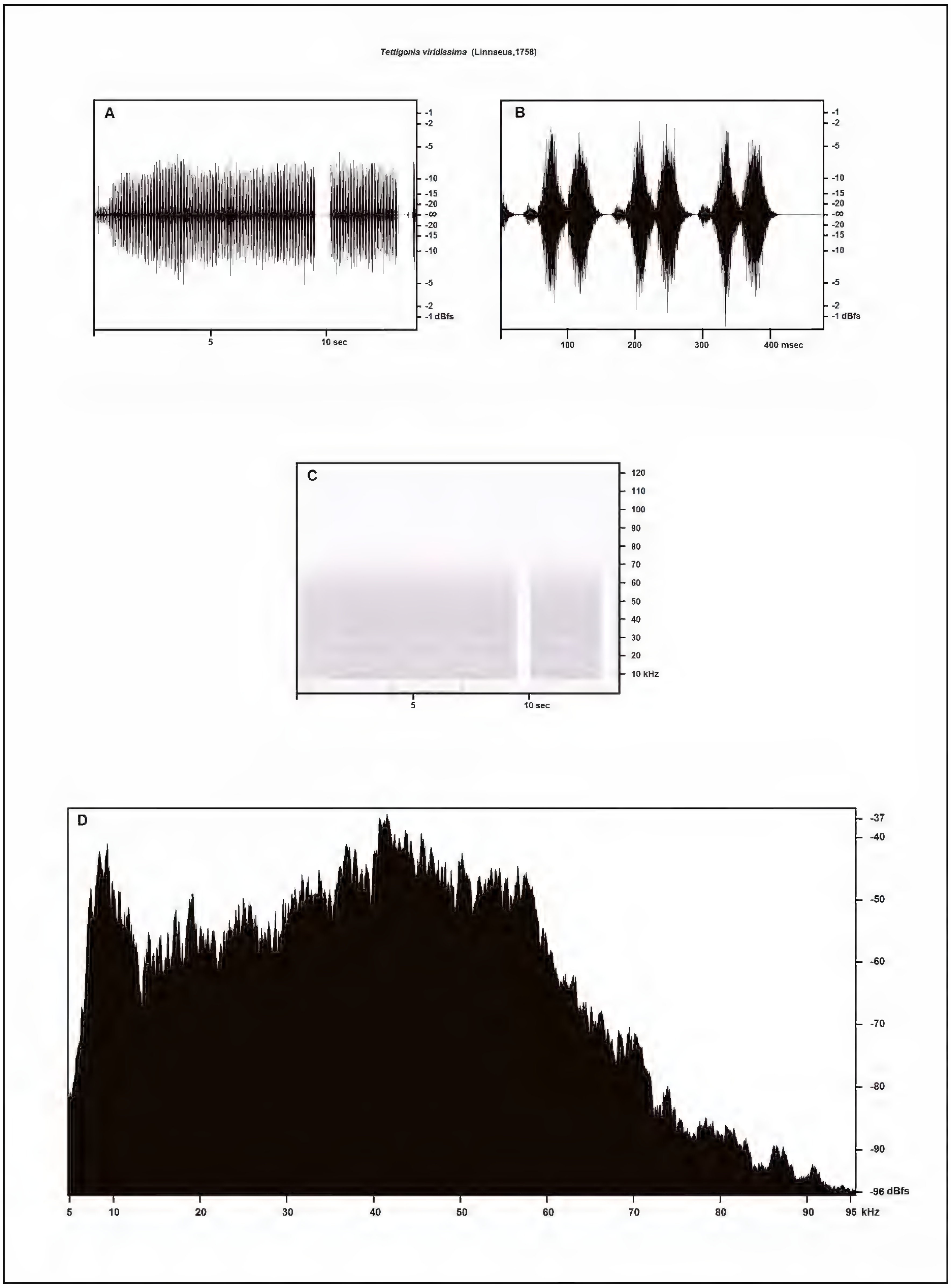


Figure 10. *Tettigonia viridissima* (Linnaeus,1758) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 6.284 sec (see Table 3).

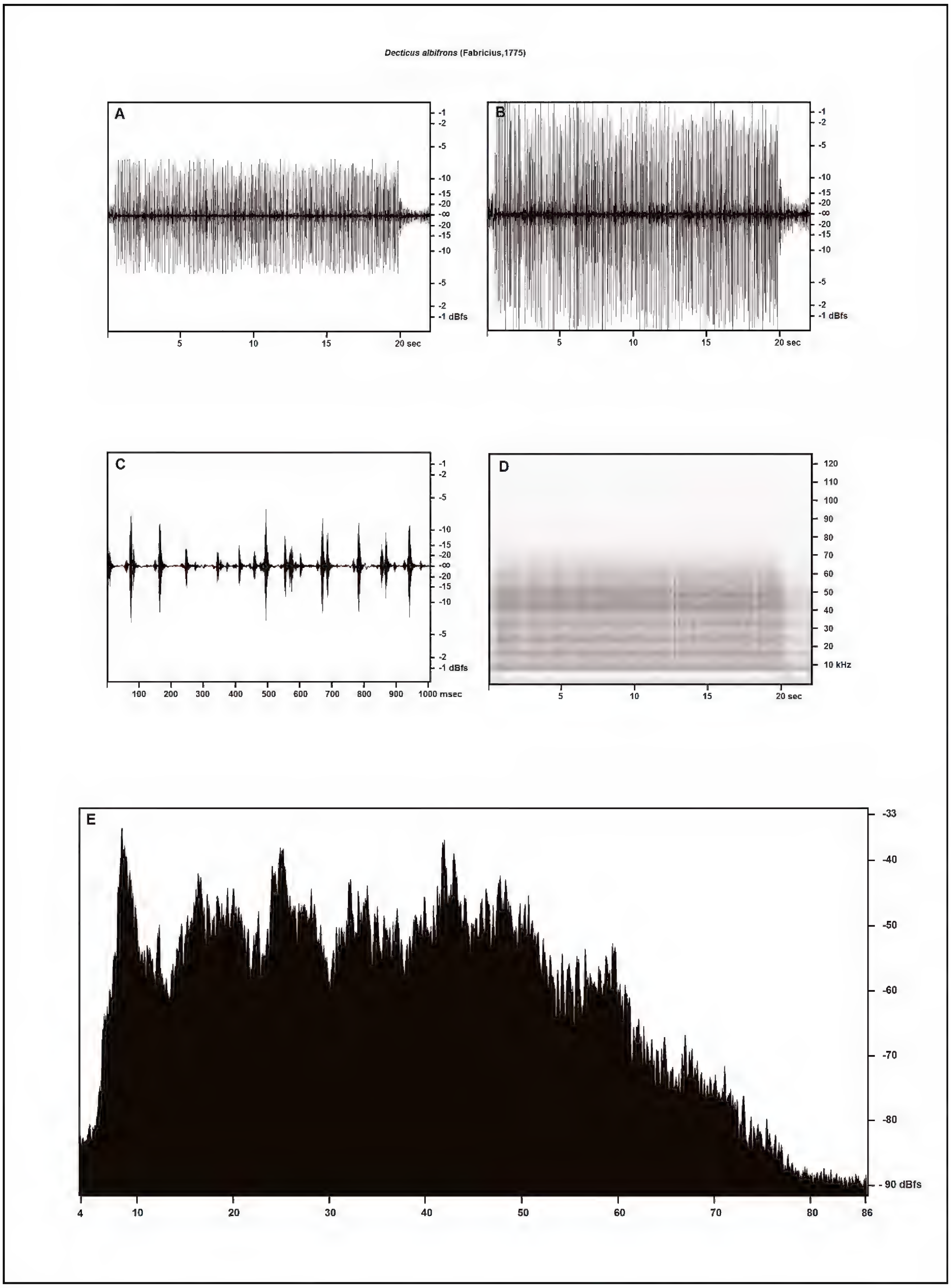


Figure 11. *Decticus albifrons* (Fabricius,1775) - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 0.901 sec (see Table 3).

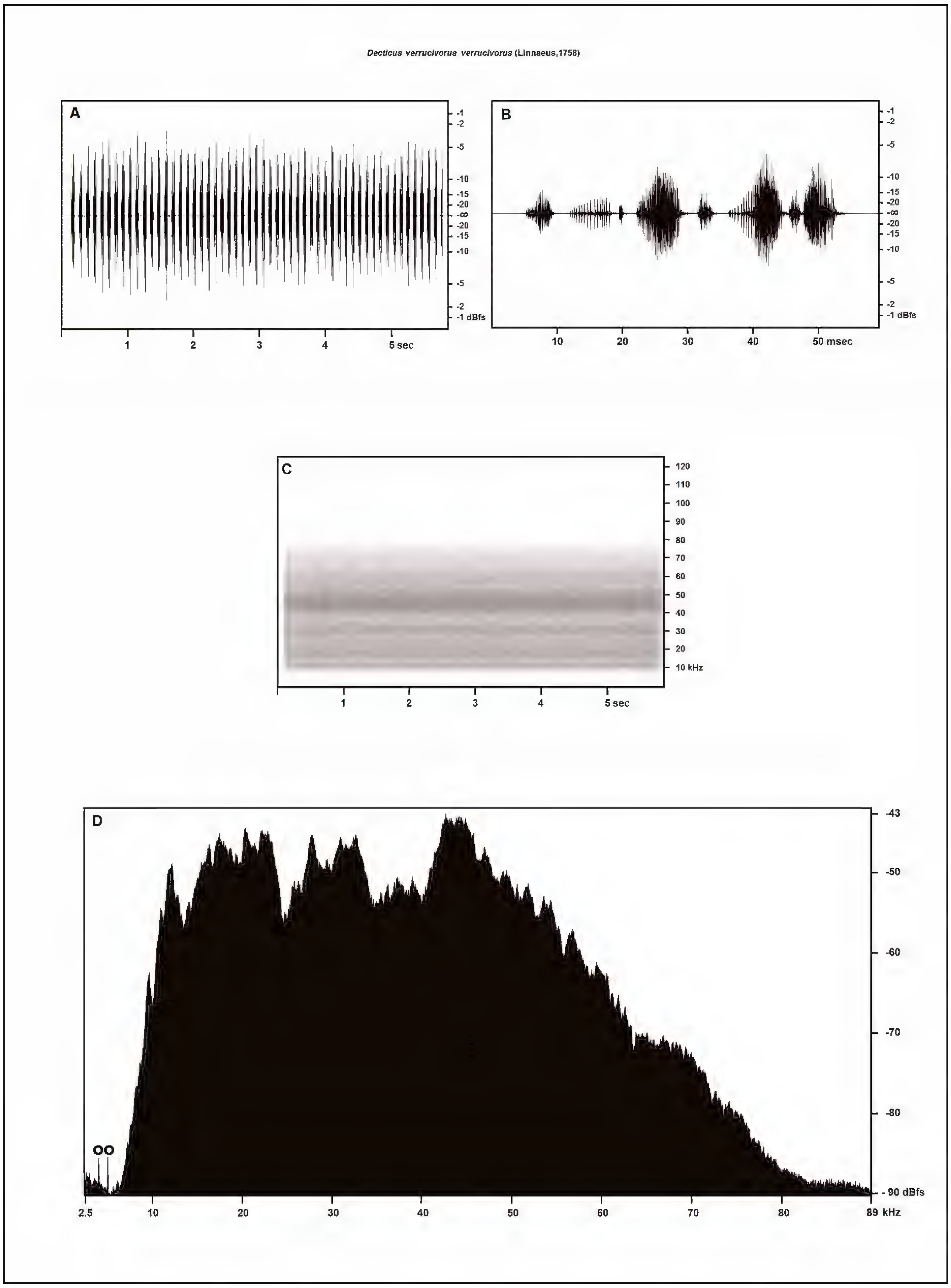


Figure 12. *Decticus verrucivorus verrucivorus* (Linnaeus,1758) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 3.779 sec (see Table 3).

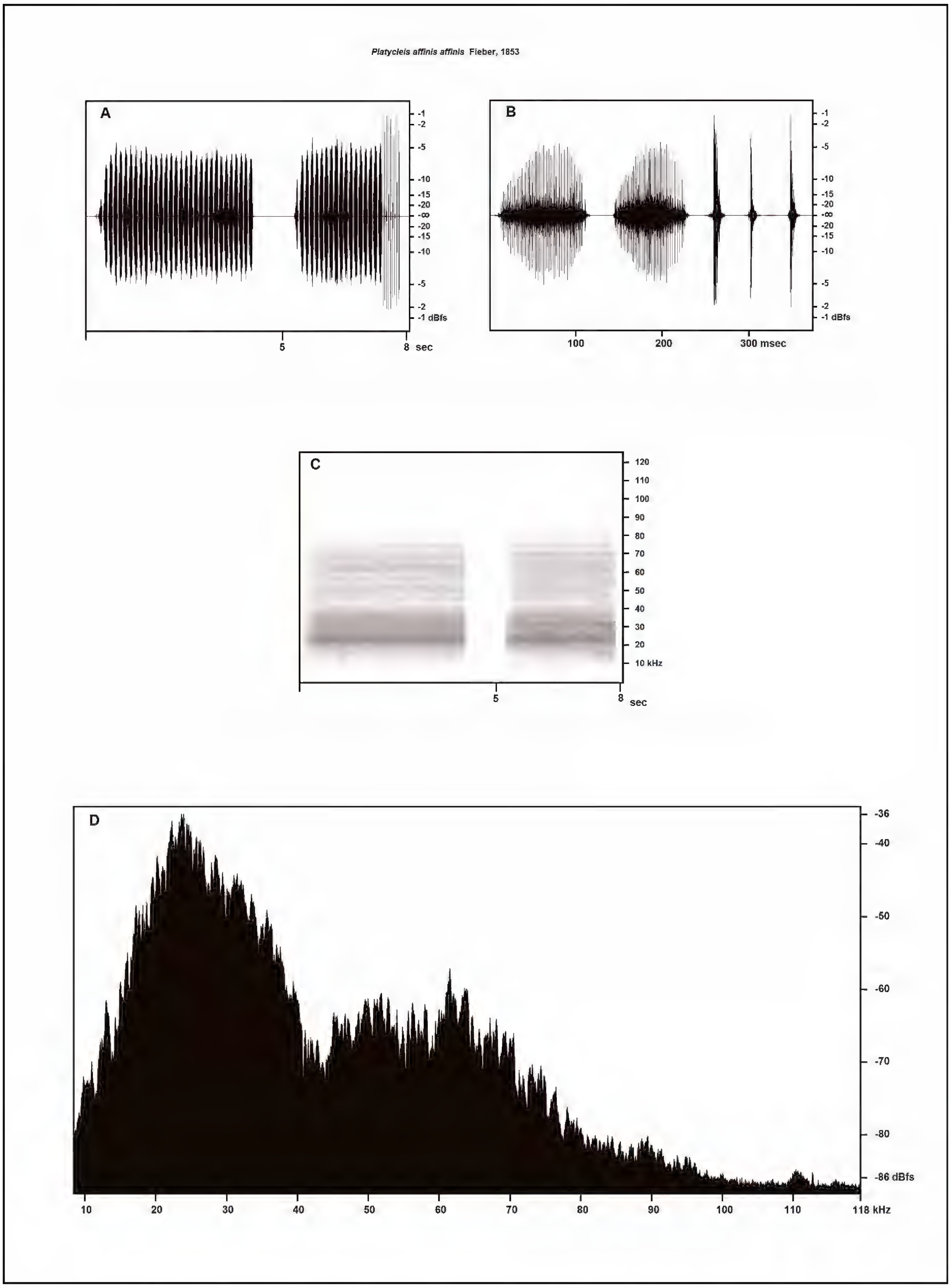


Figure 13. *Platycleis affinis affinis* Fieber, 1853 - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 4.082 sec (see Table 3).

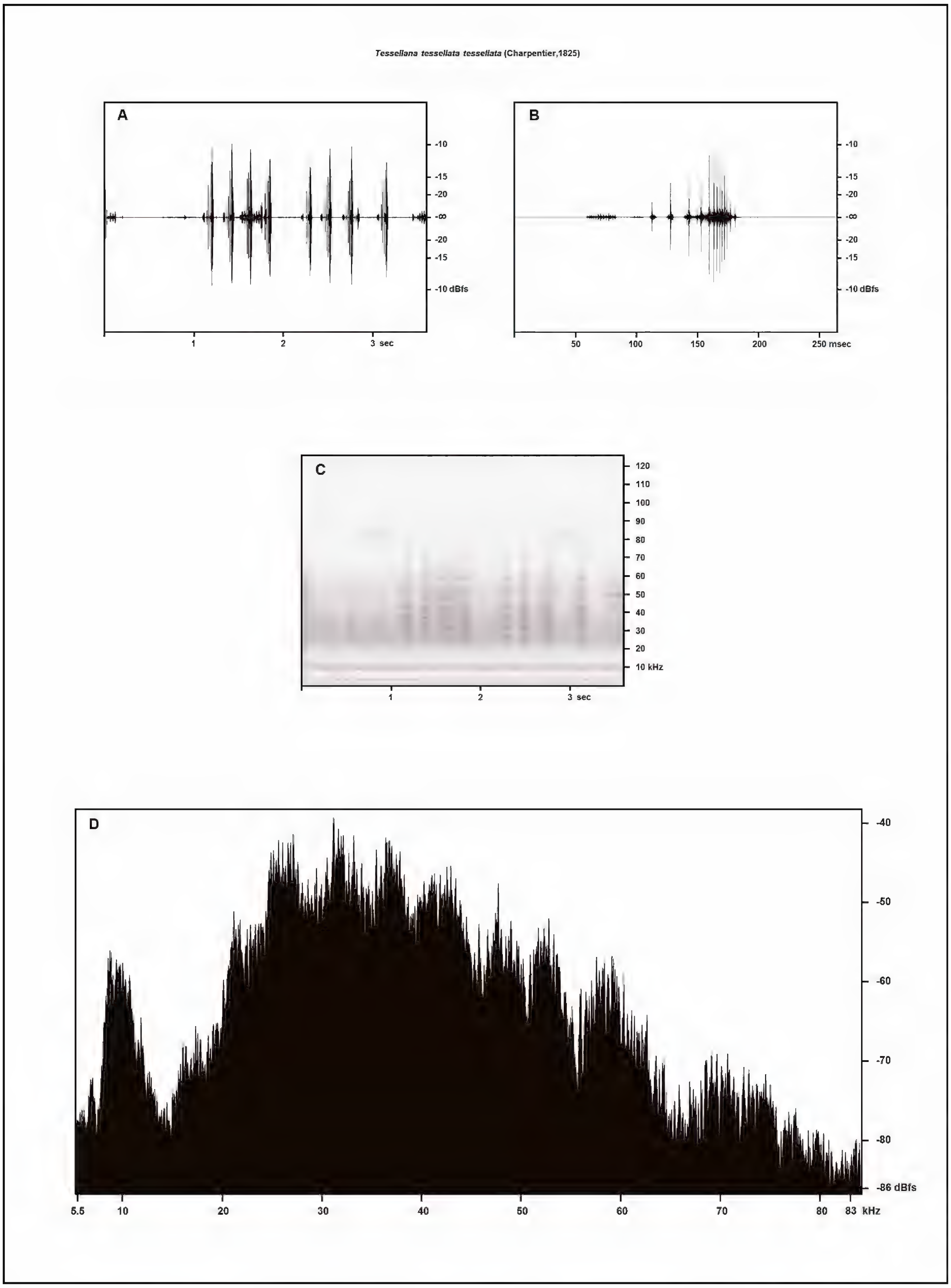


Figure 14. *Tessellana tessellata tessellata* (Charpentier,1825) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.096 sec (see Table 3).

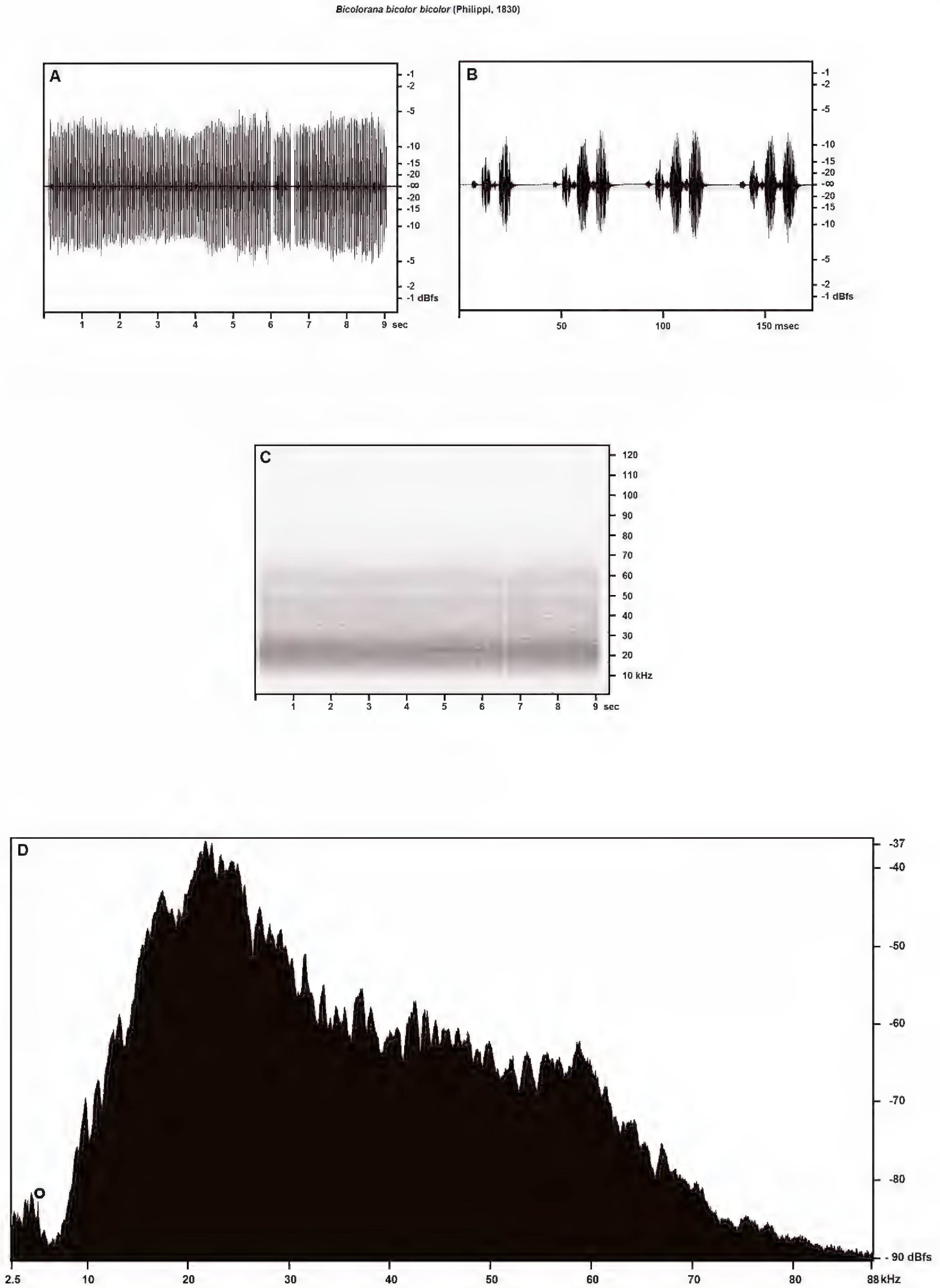


Figure 15. *Bicolorana bicolor bicolor* (Philippi, 1830) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 6.138 sec (see Table 3).

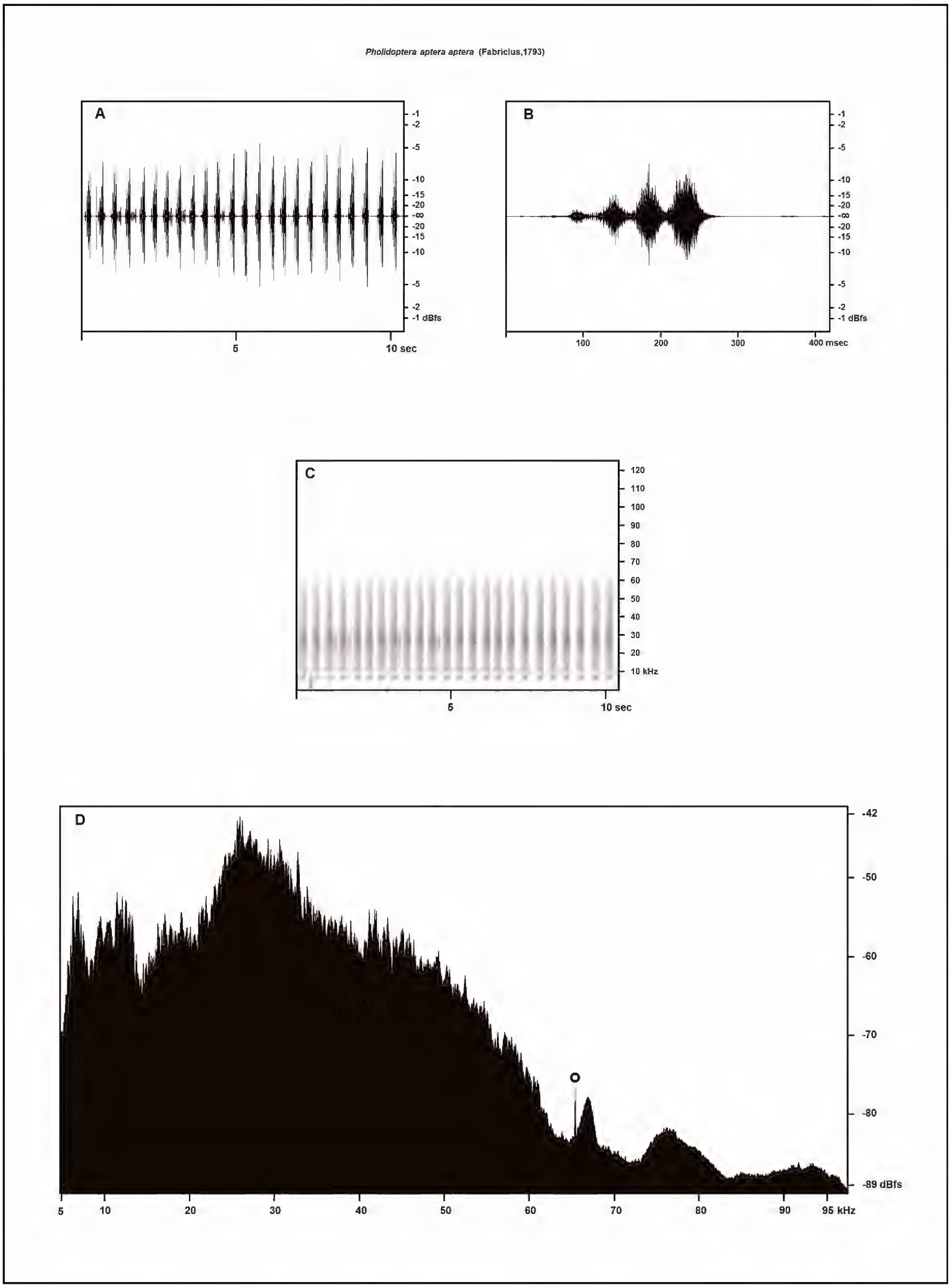


Figure 16. *Pholidoptera aptera aptera* (Fabricius,1793) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 12.173 sec (see Table 3).

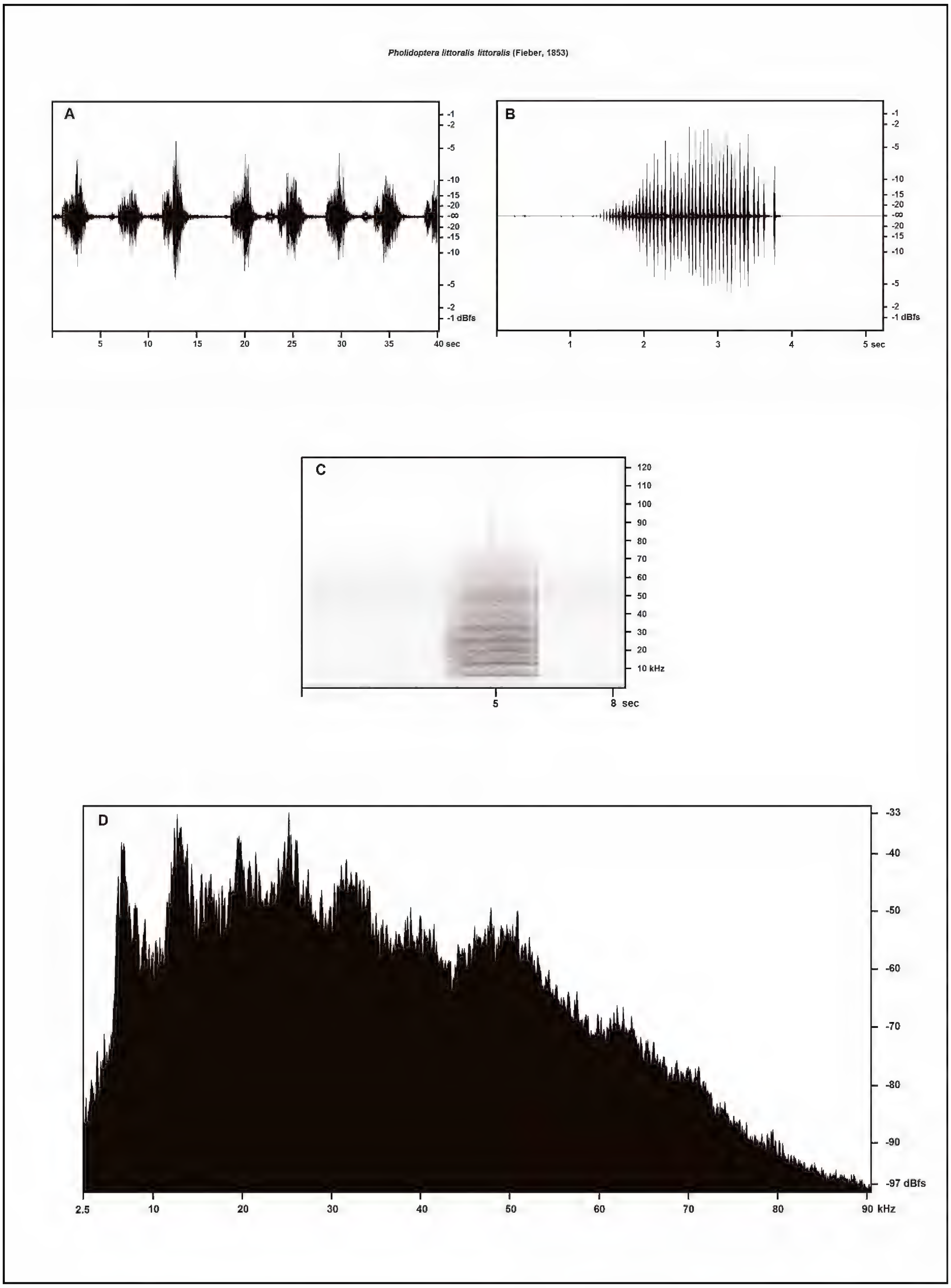


Figure 17. *Pholidoptera littoralis littoralis* (Fieber, 1853) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 2.632 sec (see Table 3).

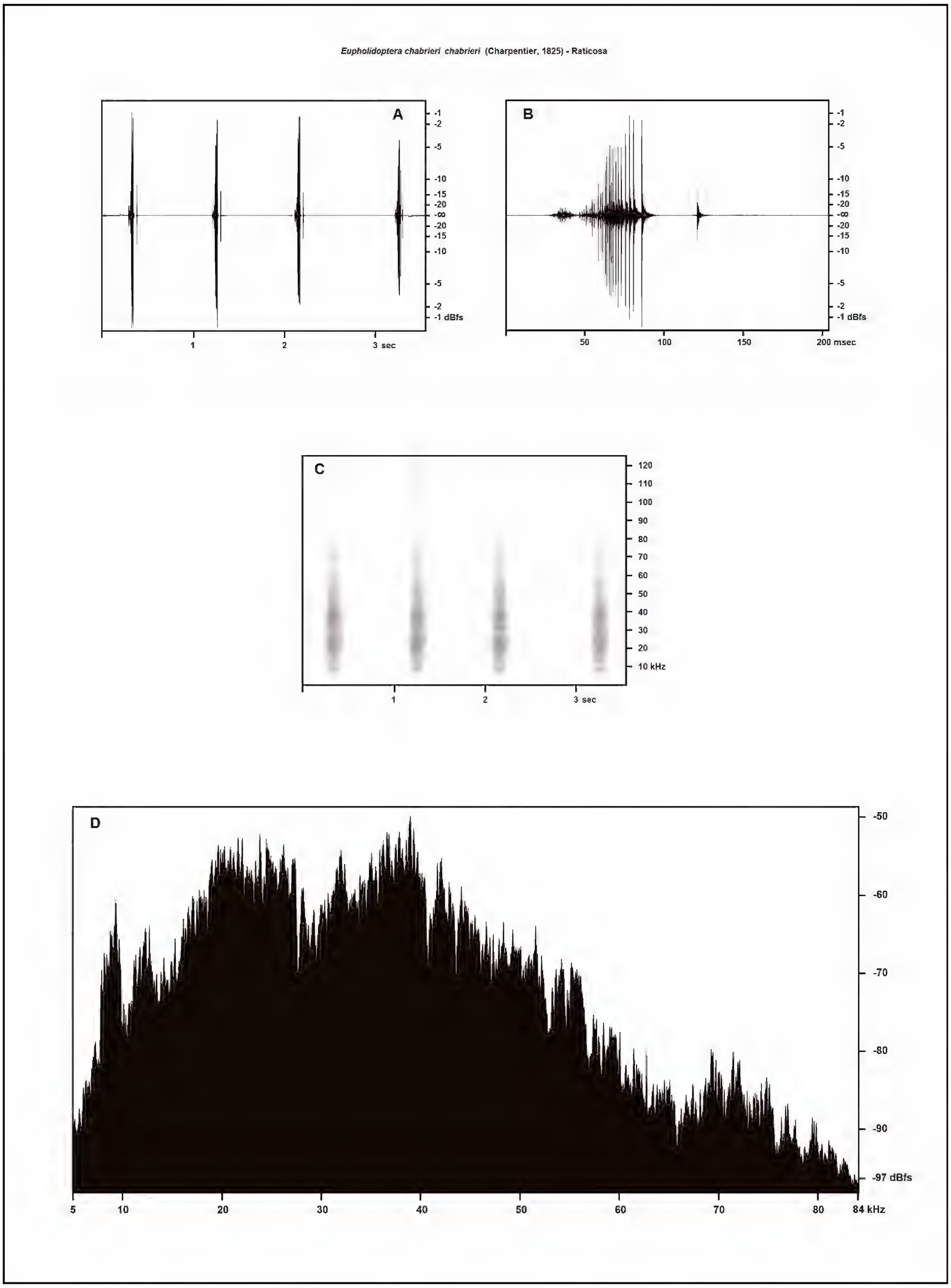
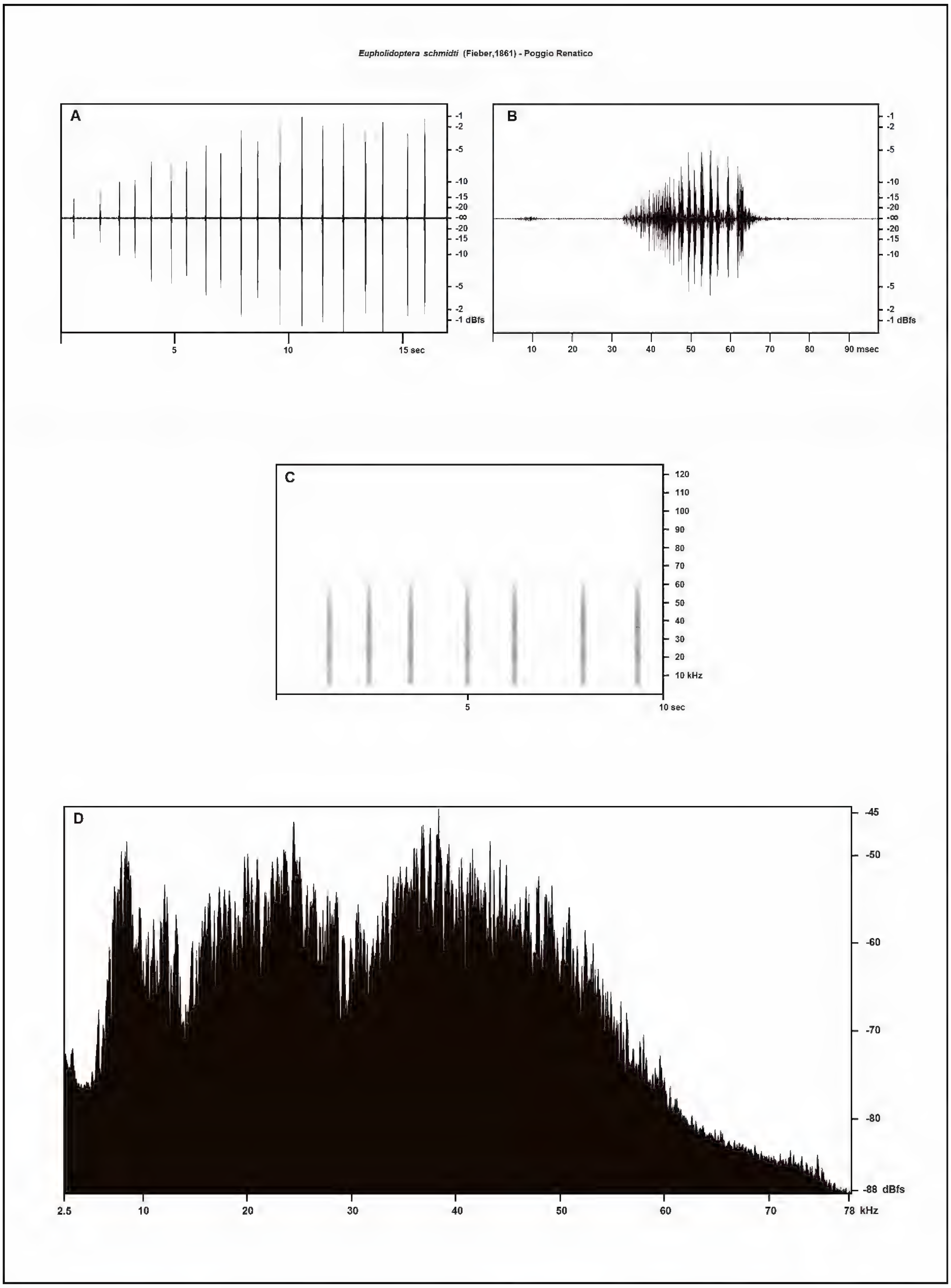


Figure 18. *Eupholidoptera chabrieri chabrieri* (Charpentier, 1825) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 3.172 sec (see Table 3).



Eupholidoptera schmidti (Fieber,1861) - Poggio Renatico

Figure 19. *Eupholidoptera schmidti* (Fieber,1861) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 3.430 sec (see Table 3).

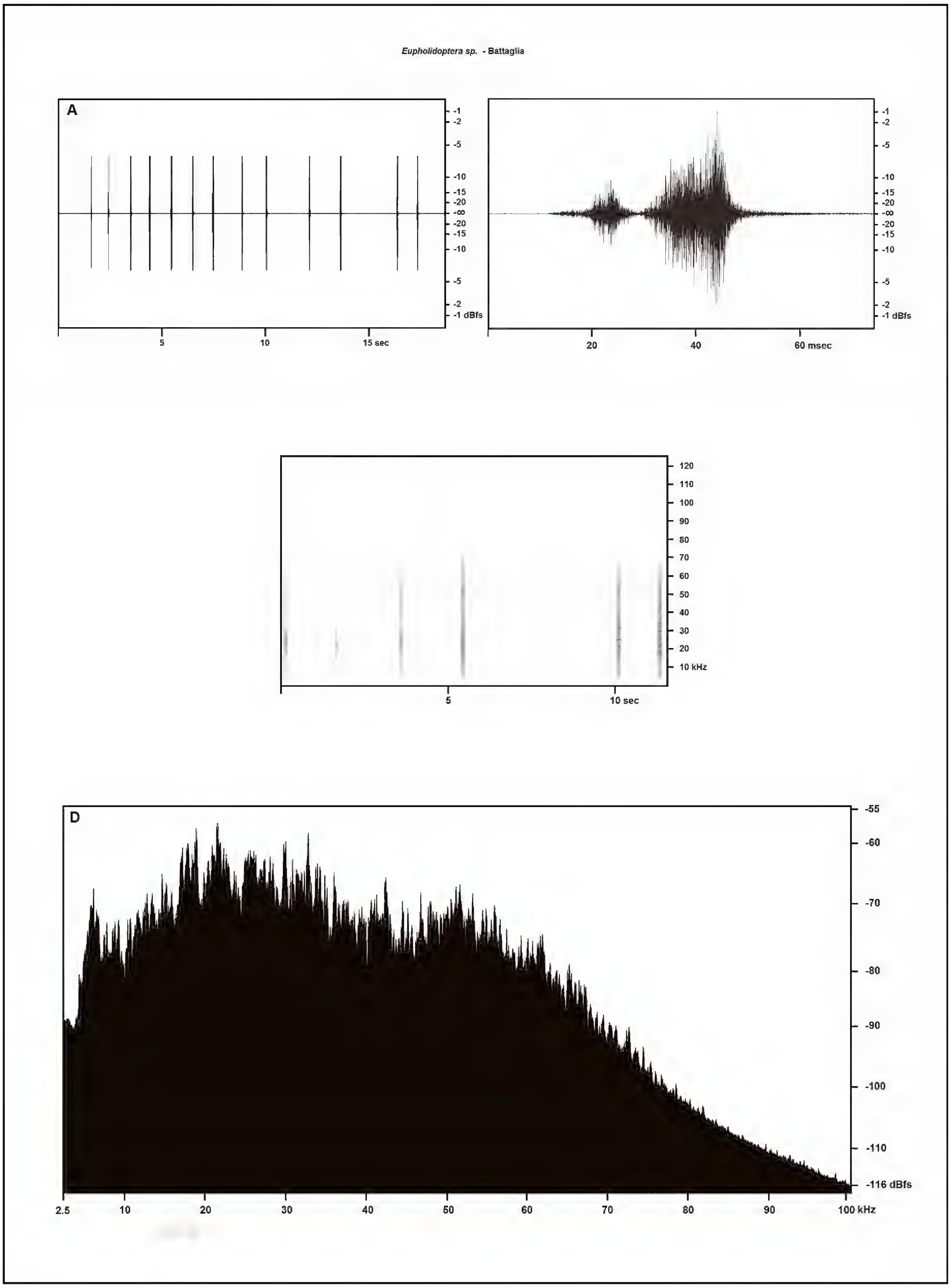


Figure 20. *Eupholidoptera* sp. Battaglia - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 17.860 sec (see Table 3).

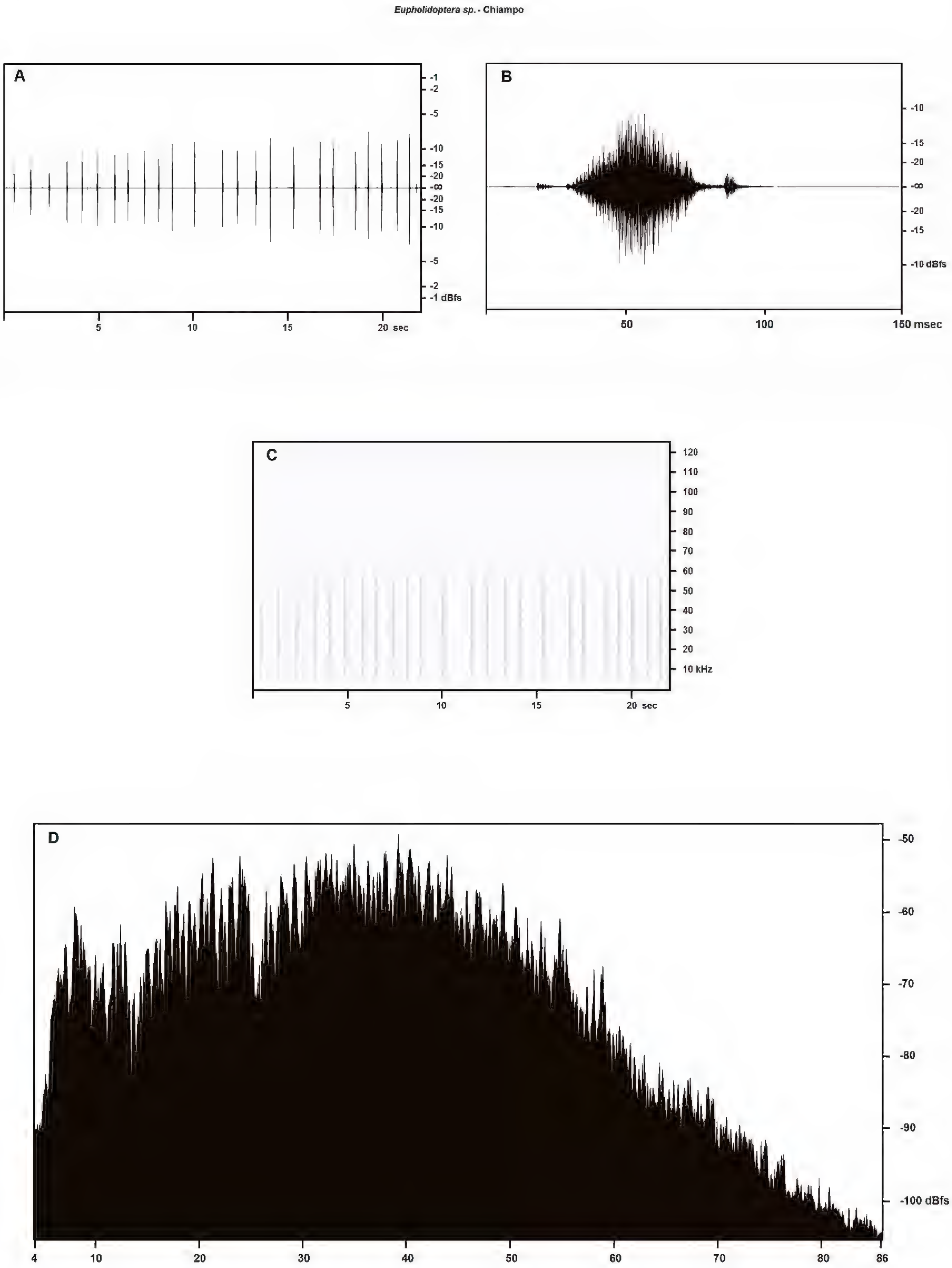


Figure 21. *Eupholidoptera* sp. Chiampo - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 3.087 sec (see Table 3).

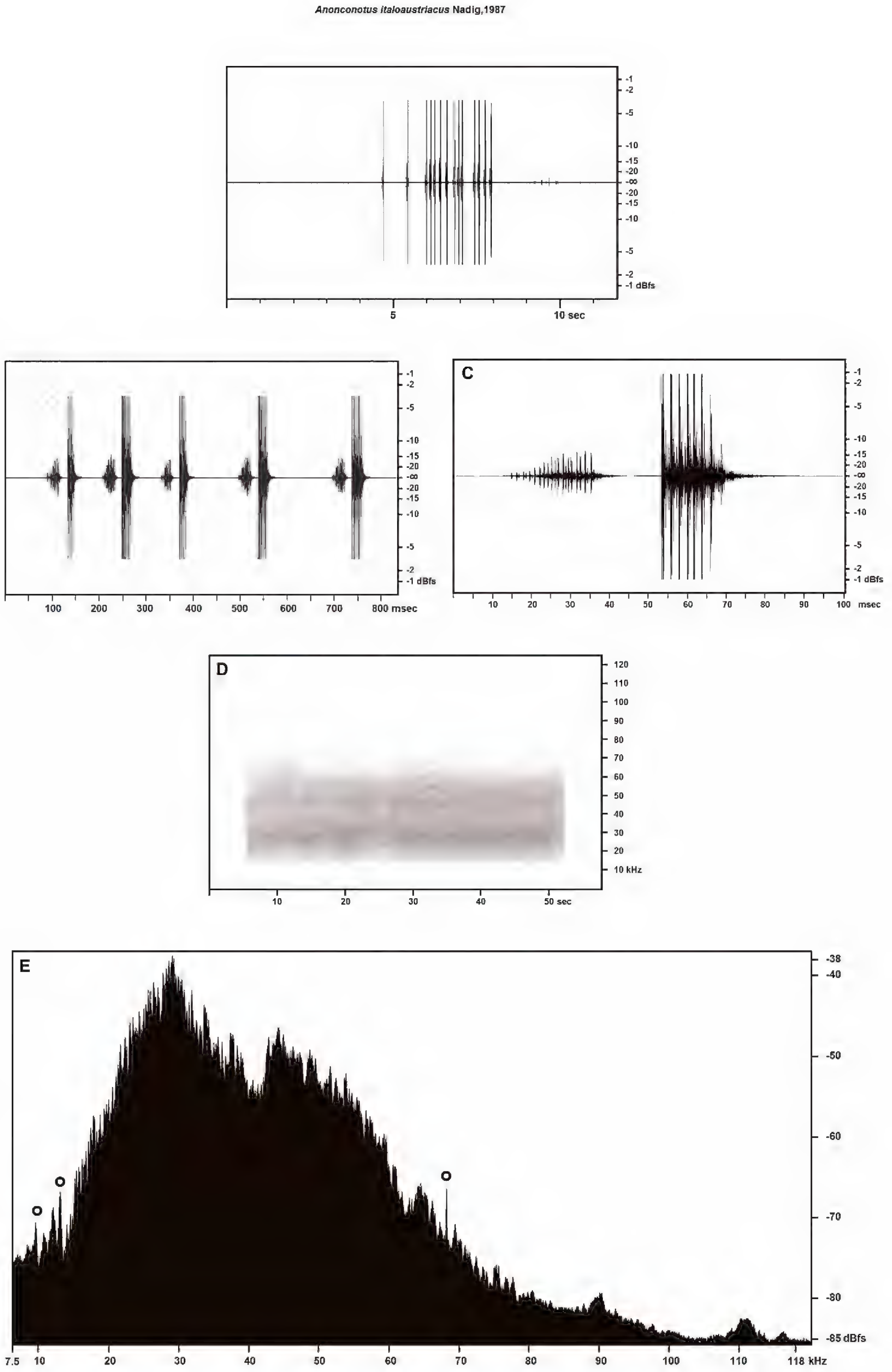


Figure 22. *Anonconotus italoaustriacus* Nadig,1987 - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 0.129 sec (see Table 3); small circles mark narrow technogenic peaks (see text).

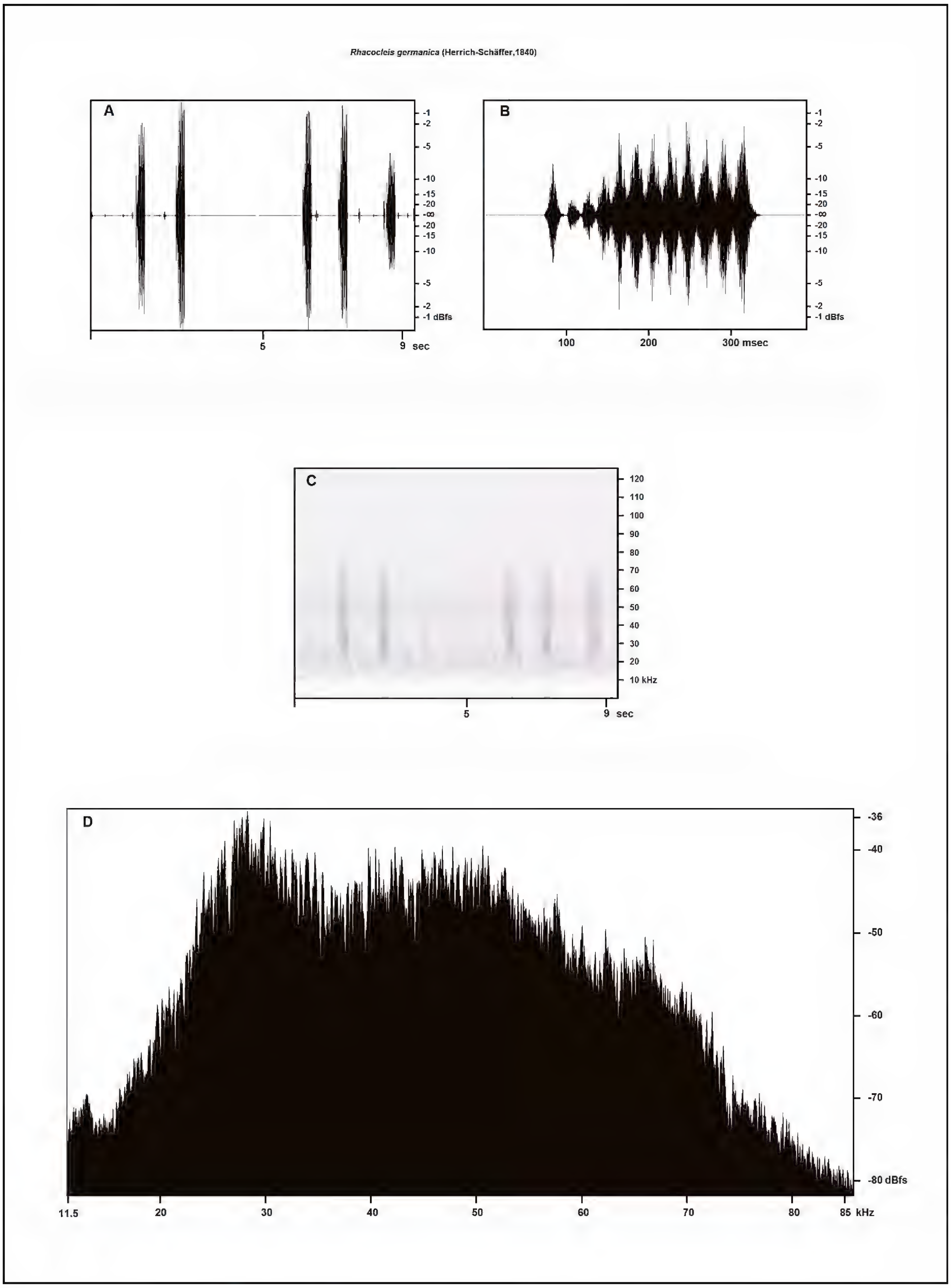


Figure 23. *Rhacocleis germanica* (Herrich-Schäffer,1840) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.306 sec (see Table 3).

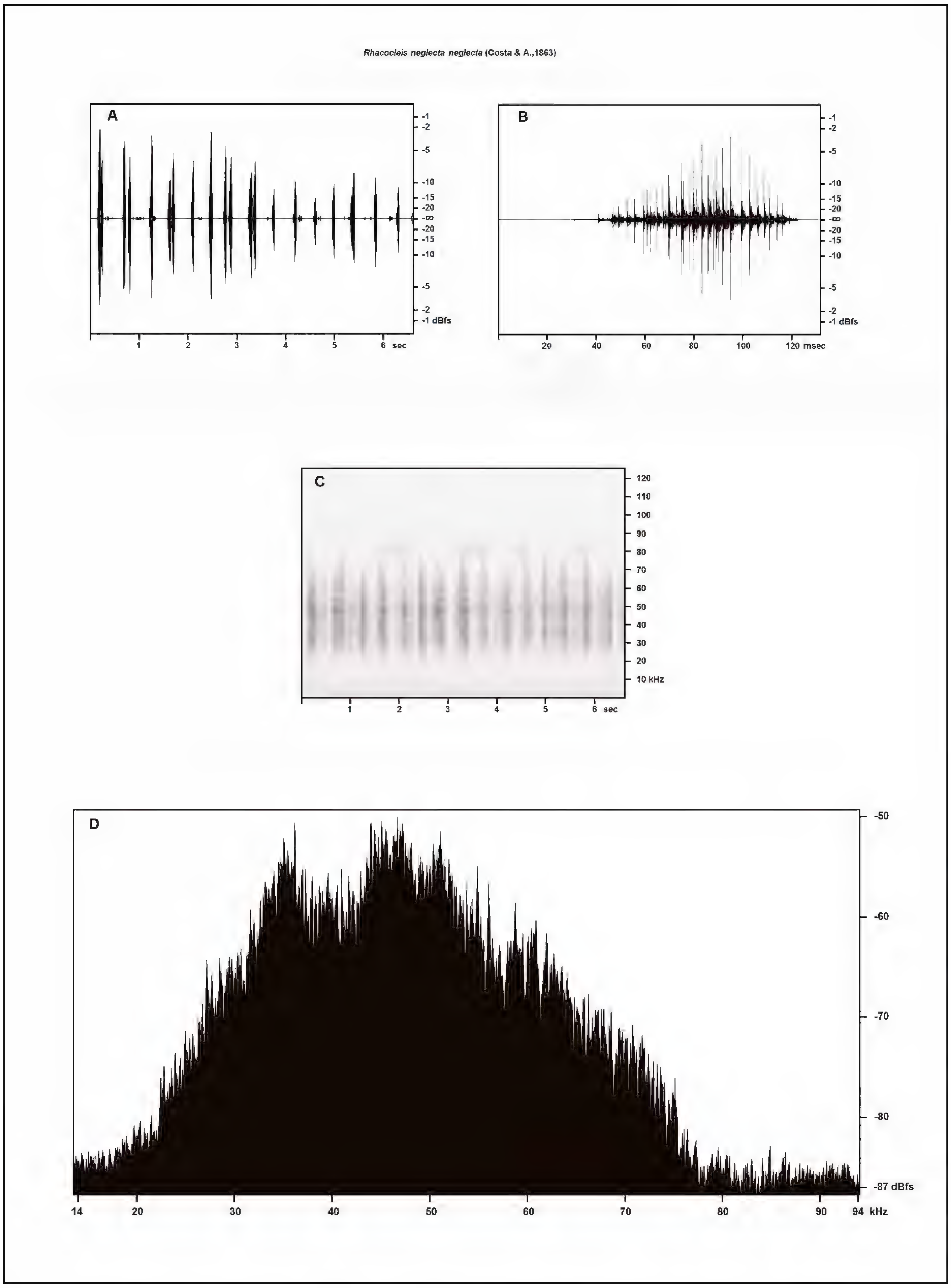


Figure 24. *Rhacocleis neglecta neglecta* (Costa A.,1863) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.616 sec (see Table 3).

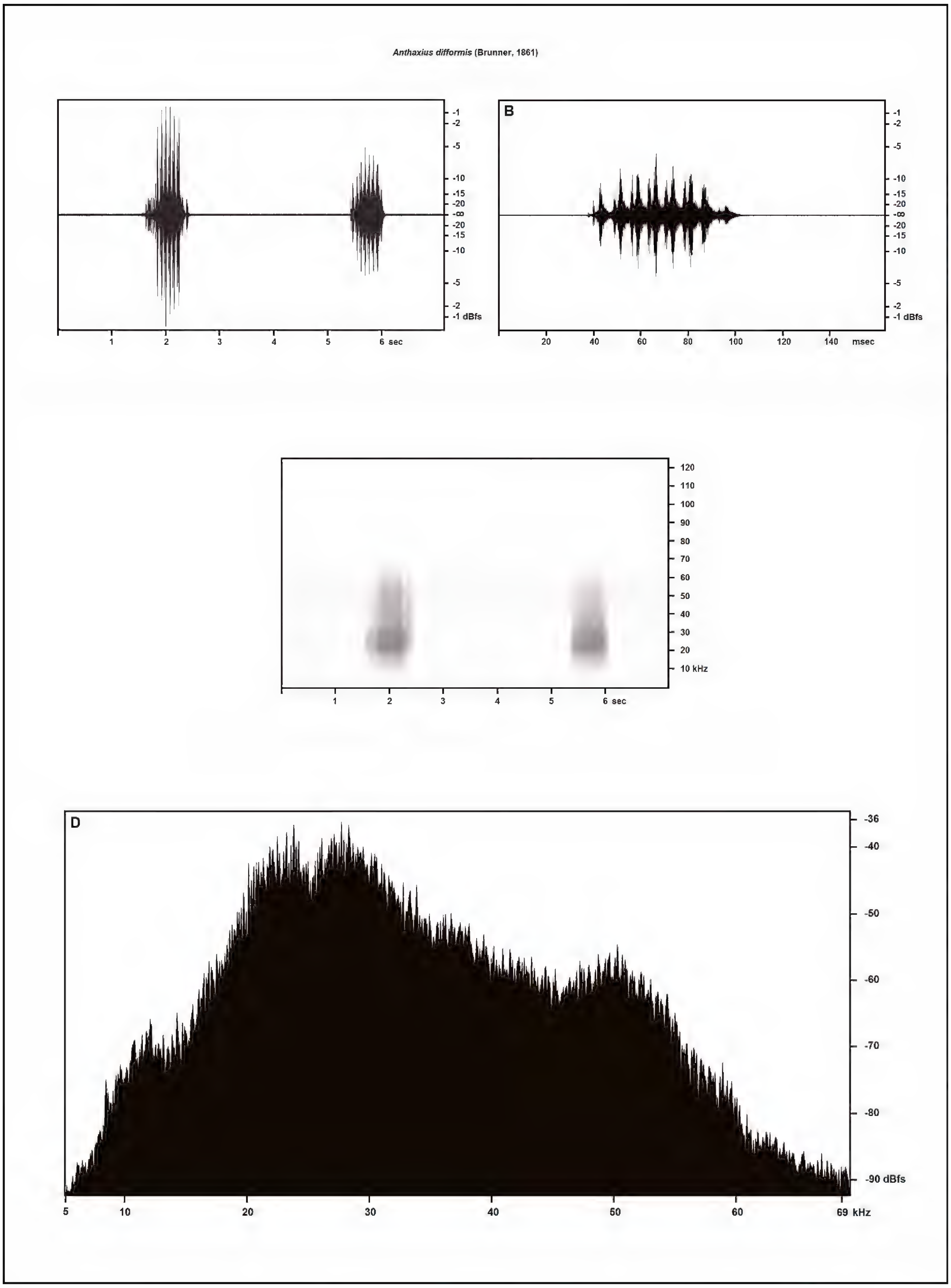


Figure 25. *Anthaxius difformis* (Brunner, 1861) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 1.145 sec (see Table 3).

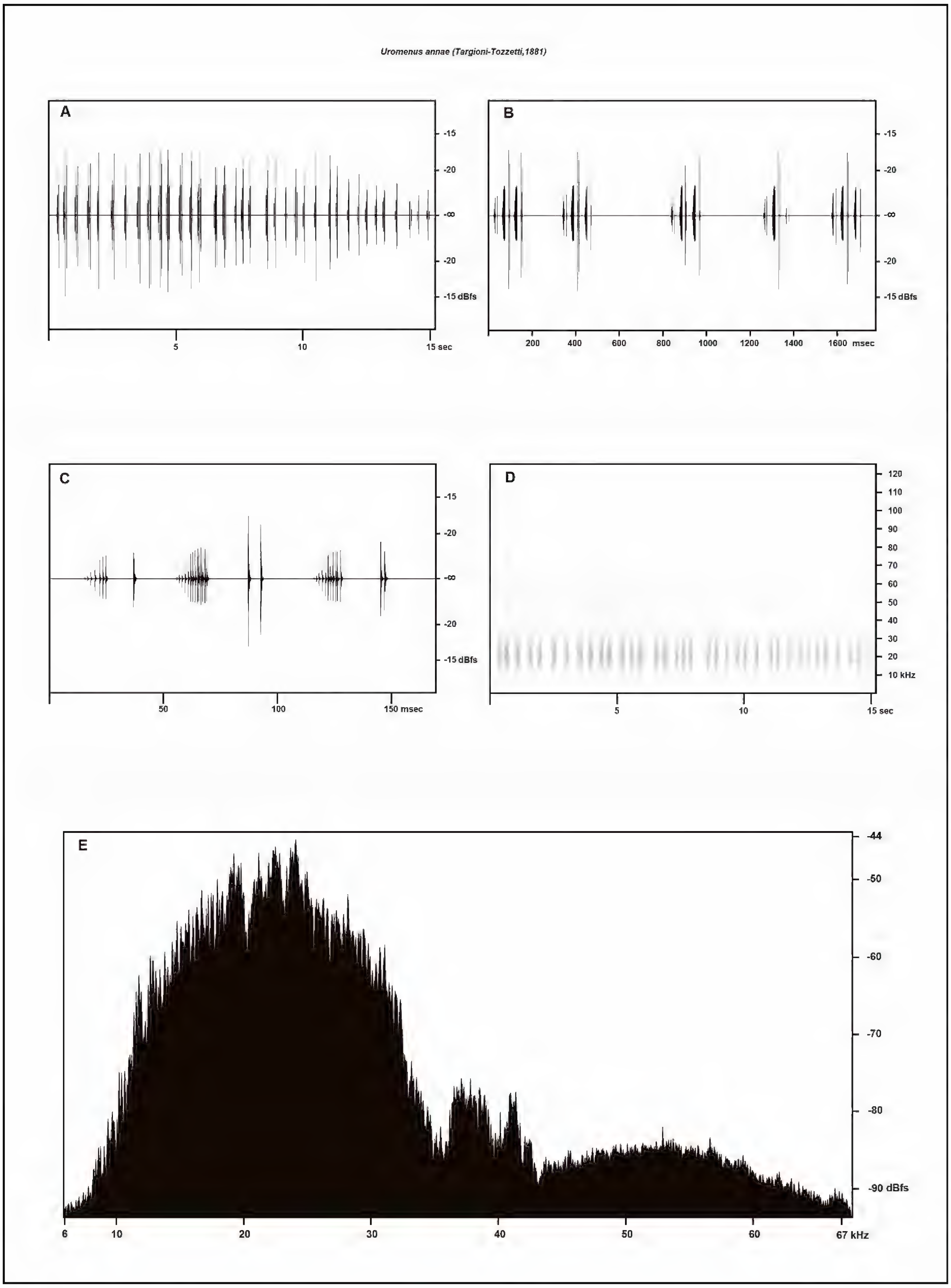


Figure 26. *Uromenus annae* (Targioni-Tozzetti, 1881) - A, B, C: envelope in three increasing levels of detail, D: spectrogram, E: frequency analysis - 1.960 sec (see Table 3).

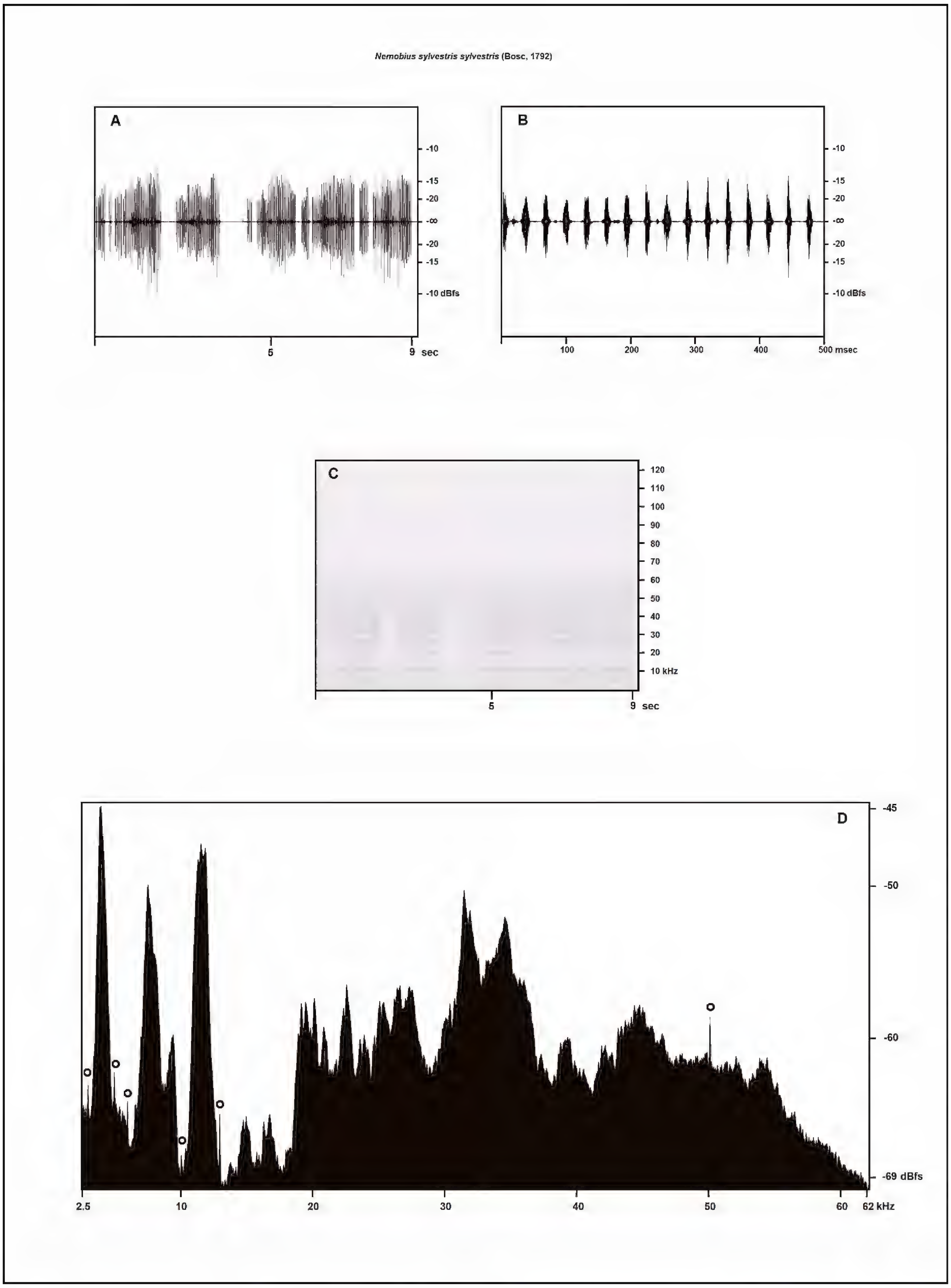


Figure 27. *Nemobius sylvestris sylvestris* (Bosc, 1792) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 8.532 sec (see Table 3); peaks marked with a small circle are artefacts caused by the usage of 150cm USB cable with Ultramic 250.

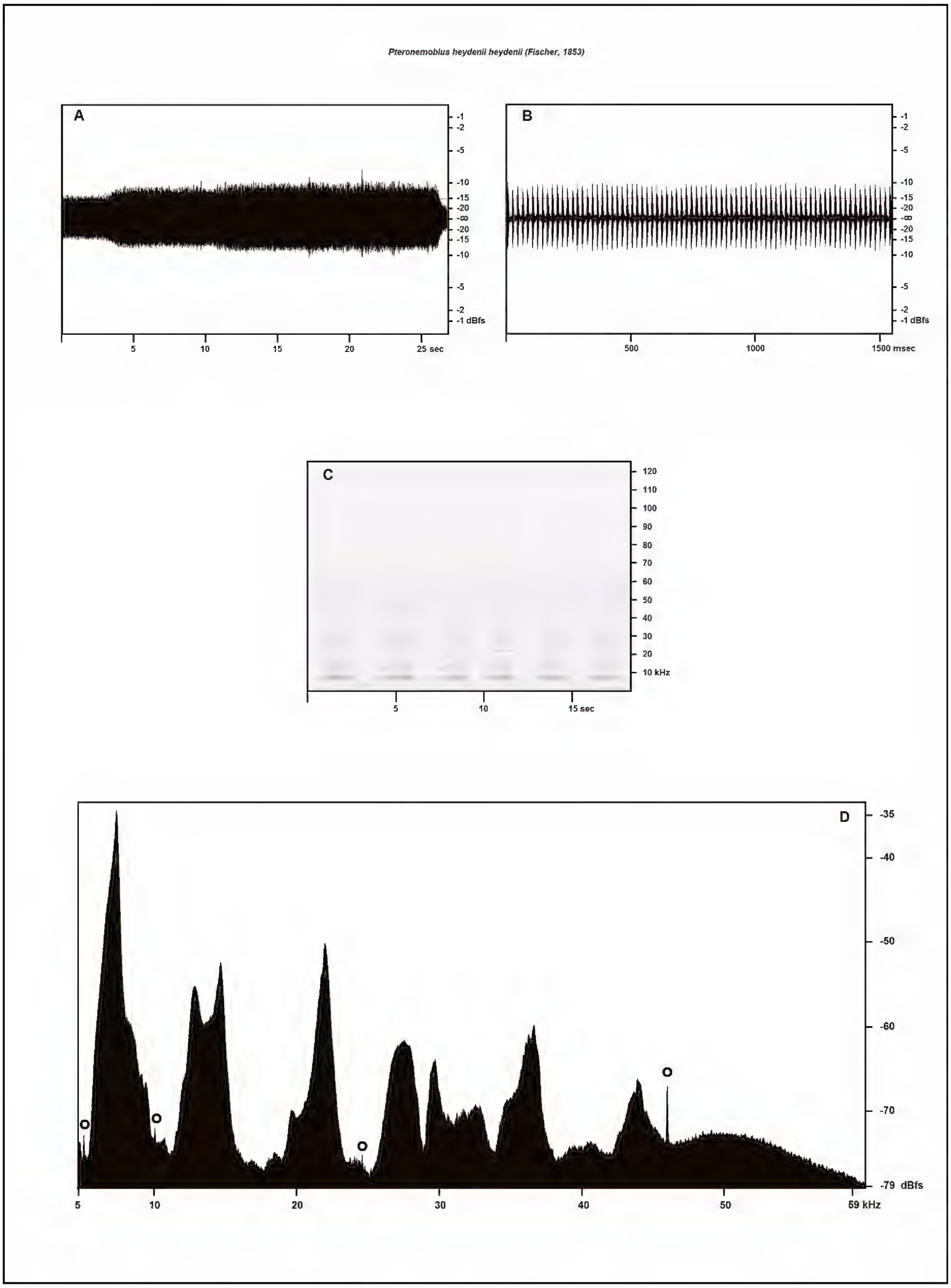


Figure 28. *Pteronemobius heydenii heydenii* (Fischer, 1853) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 8.439 sec (see Table 3); peaks marked with a small circle are artefacts caused by the usage of 150cm USB cable with Ultramic 250.

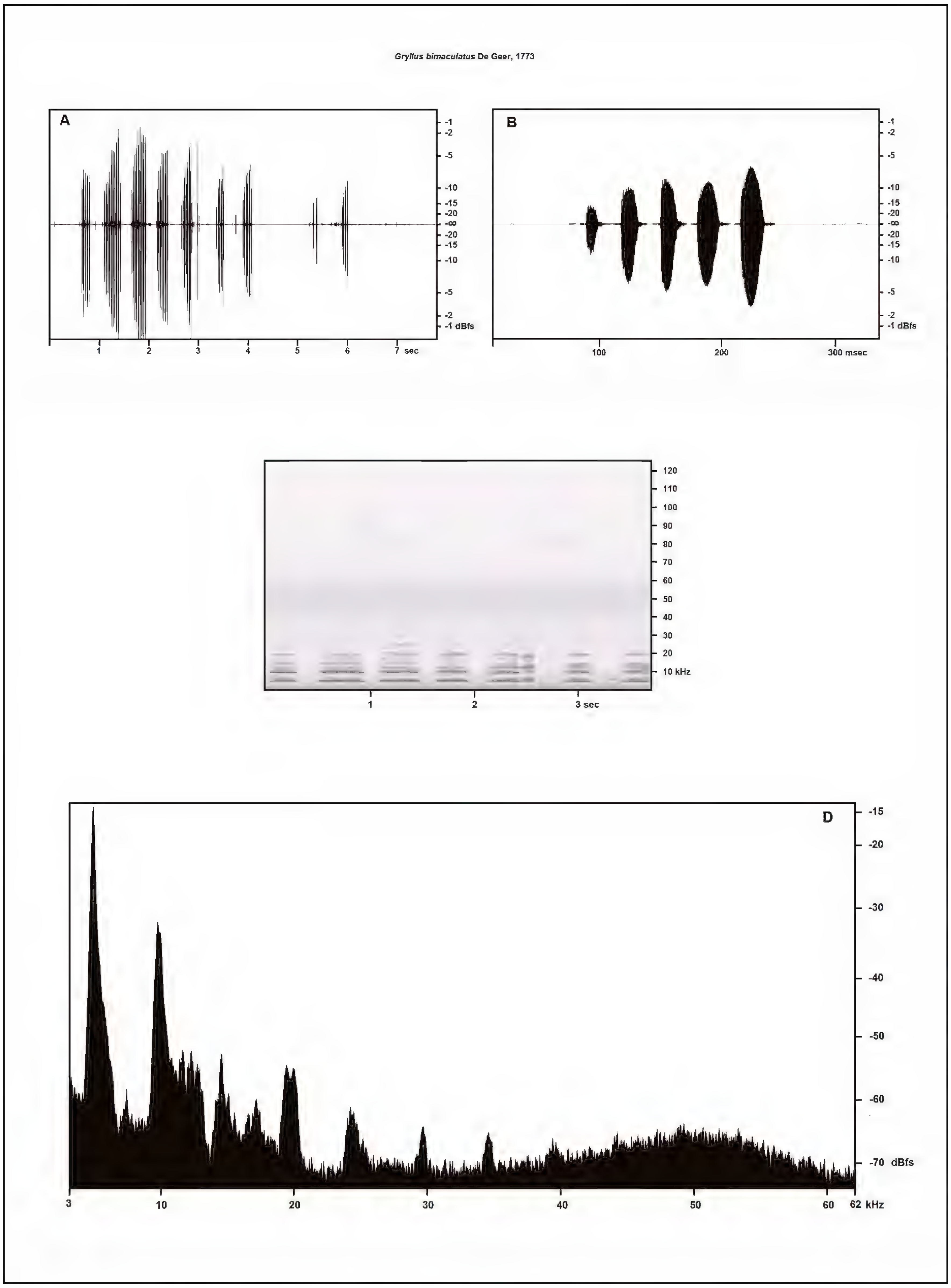


Figure 29. *Gryllus bimaculatus* De Geer, 1773 - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.439 sec (see Table 3).

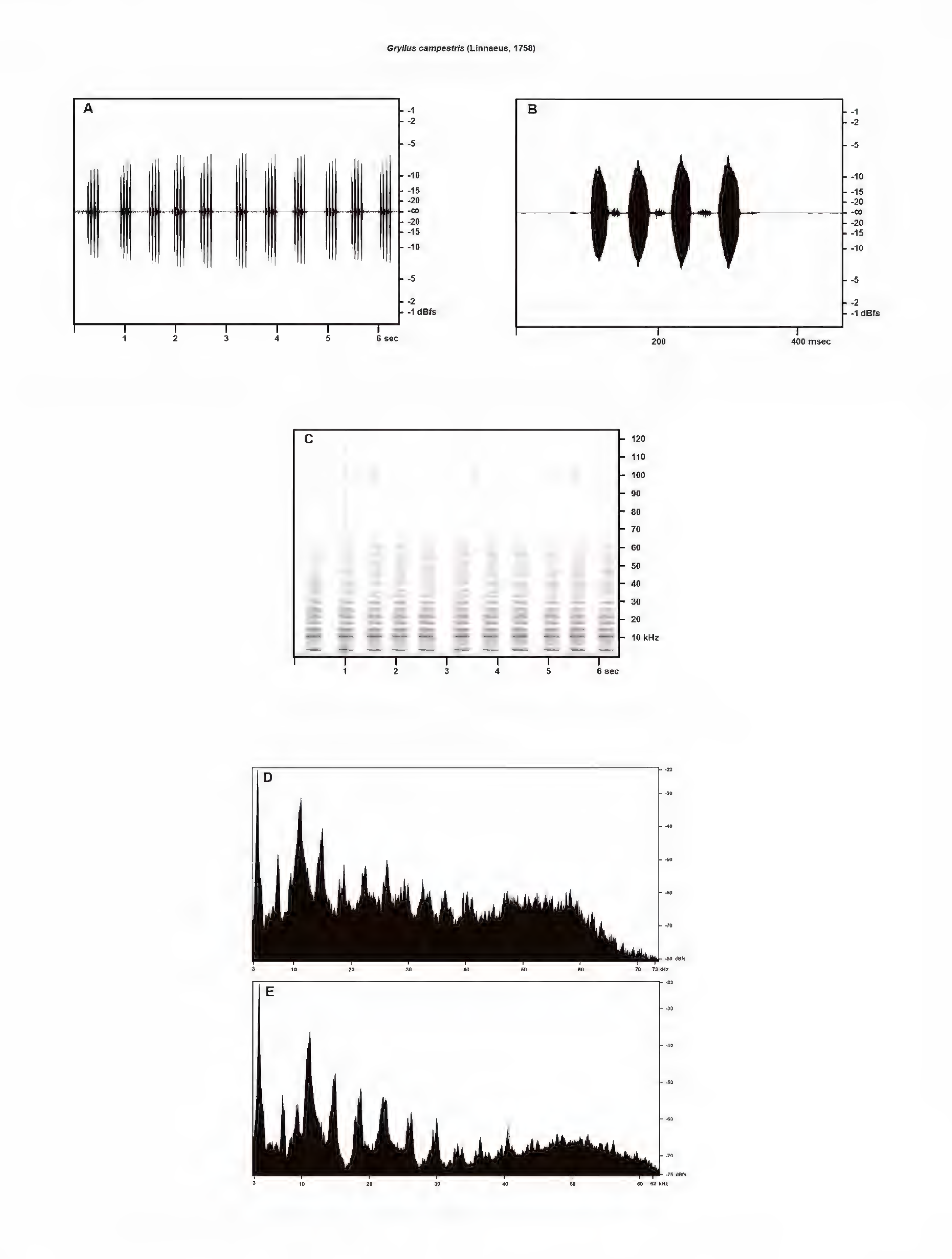


Figure 30. *Gryllus campestris* Linnaeus, 1758 - A, B: envelope at two increasing levels of detail, C: spectrogram, D, E: frequency analyses of two specimens recorded at the same location and at the same time, showing the exact coincidence of fundamental frequency, good correspondence of peaks above 10 kHz, and different timbre in the 5-10 kHz band as well as, respectively, a less or more sharp definition of frequency peaks - respectively, 4.942 and 4.719 sec (see Table 3).

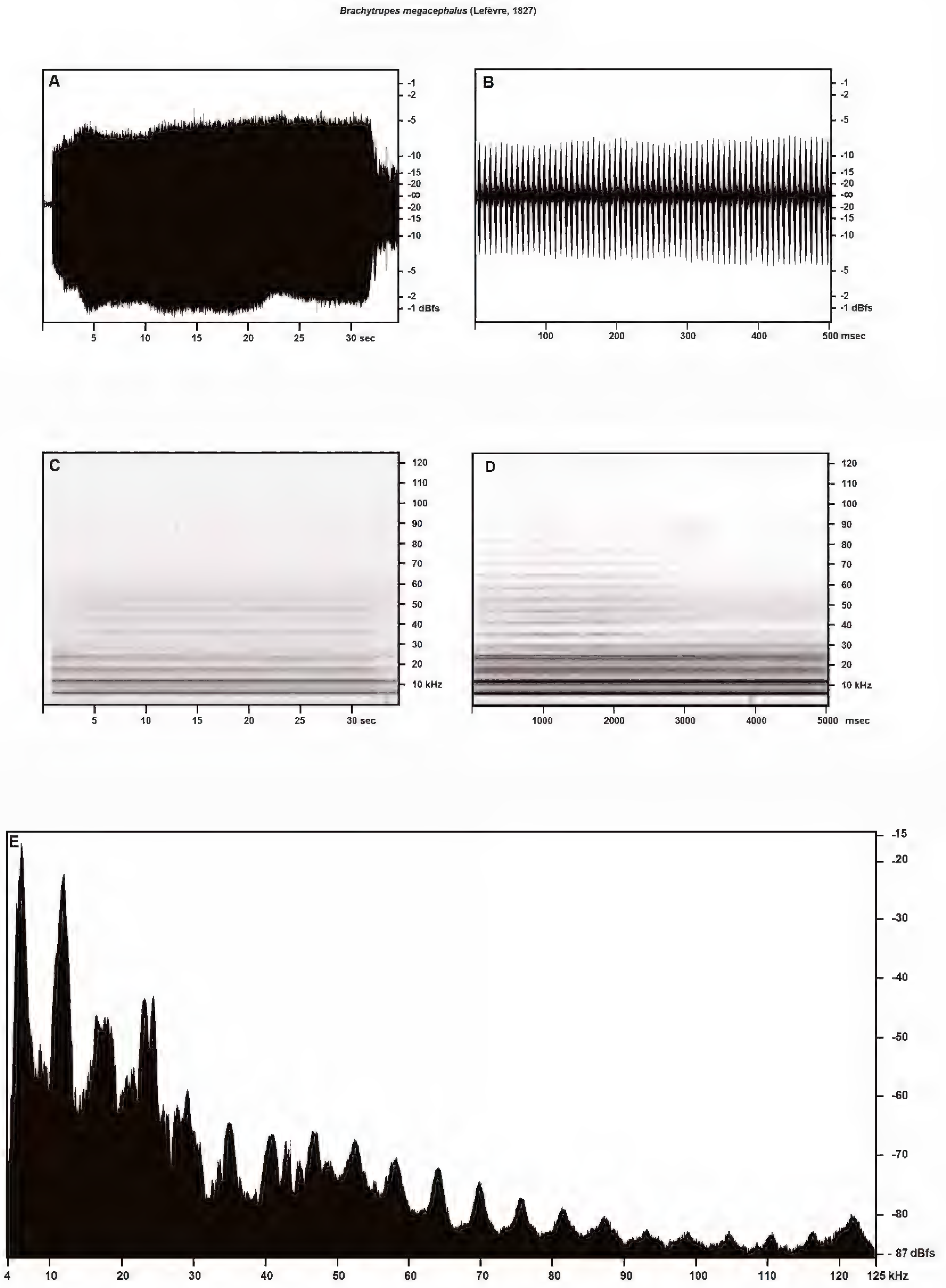


Figure 31. *Brachytrupes megacephalus* (Lefèvre, 1827) - A, B: envelope at two increasing levels of detail, C,D: spectrogram at two increasing levels of detail, E: frequency analysis - 3.003 sec (see Table 3).

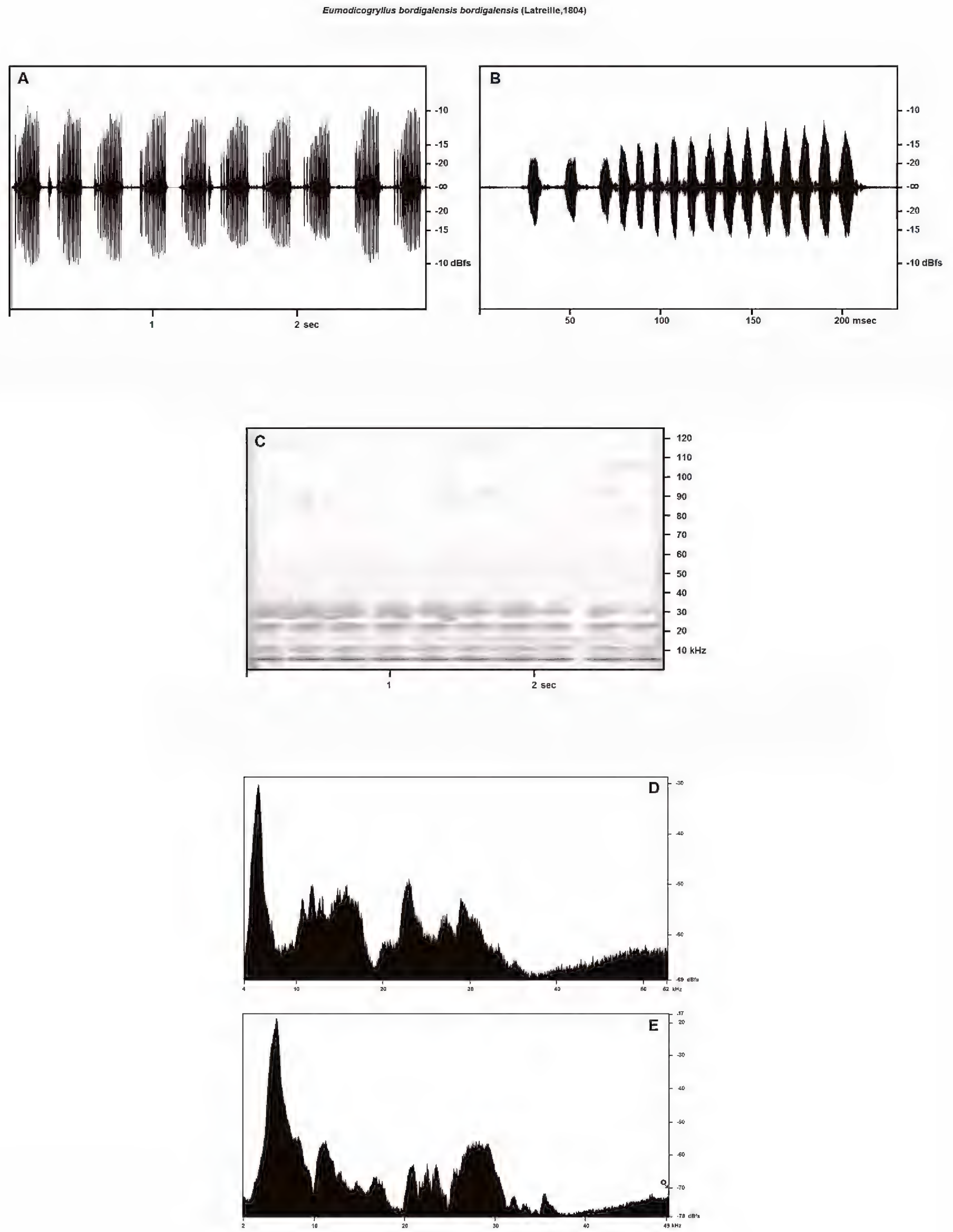


Figure 32. *Eumodicogryllus bordigalensis bordigalensis* (Latreille,1804) - A, B: envelope at two increasing levels of detail, C: spectrogram, D, E: frequency analyses - above, specimen singing in natural conditions on open ground - 4.571 sec (see Table 3); below, specimen singing from under a manhole cover, whose song is affected by selective frequency amplification and damping.

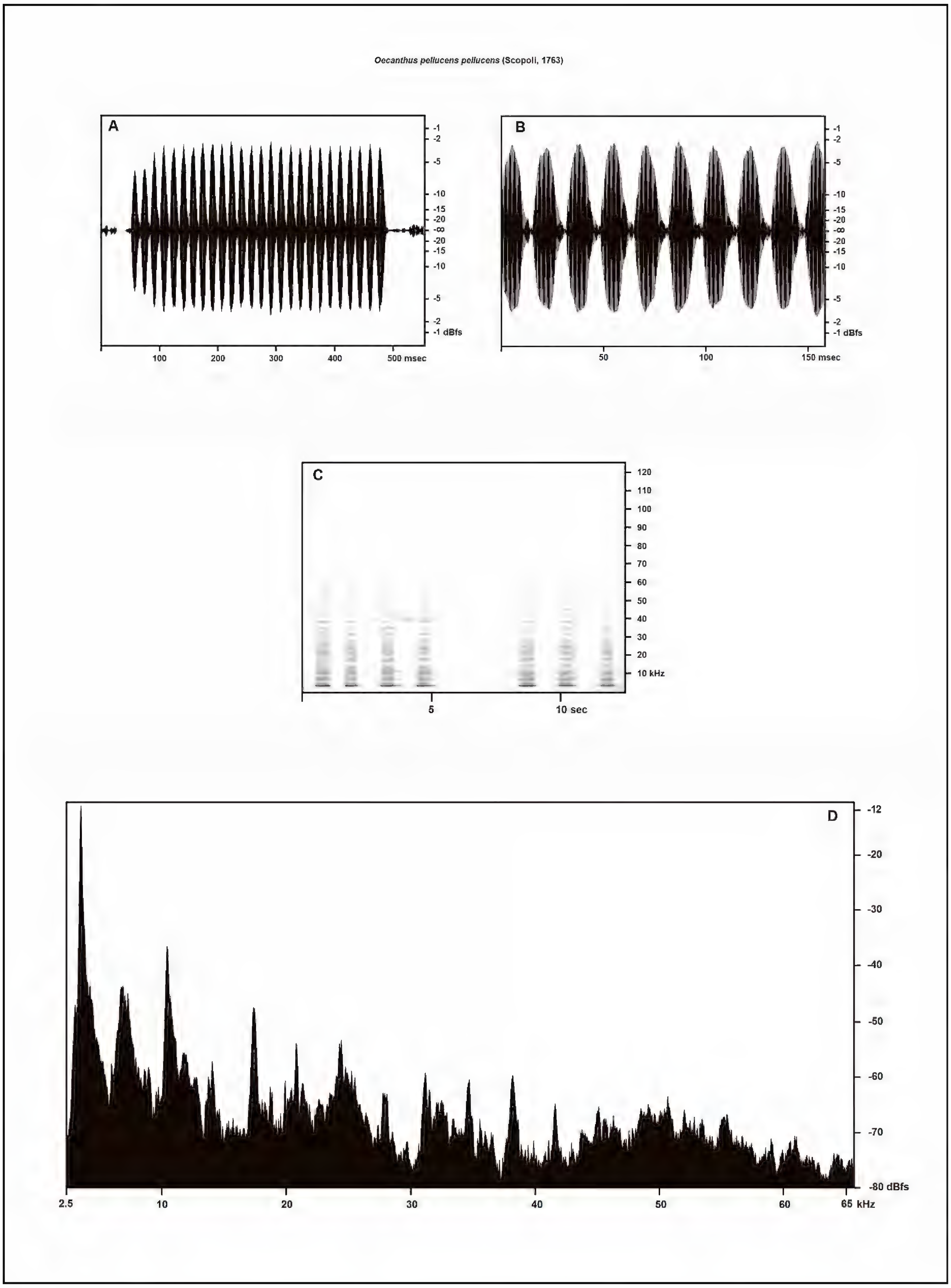


Figure 33. *Oecanthus pellucens pellucens* (Scopoli, 1763) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.578 sec (see Table 3).

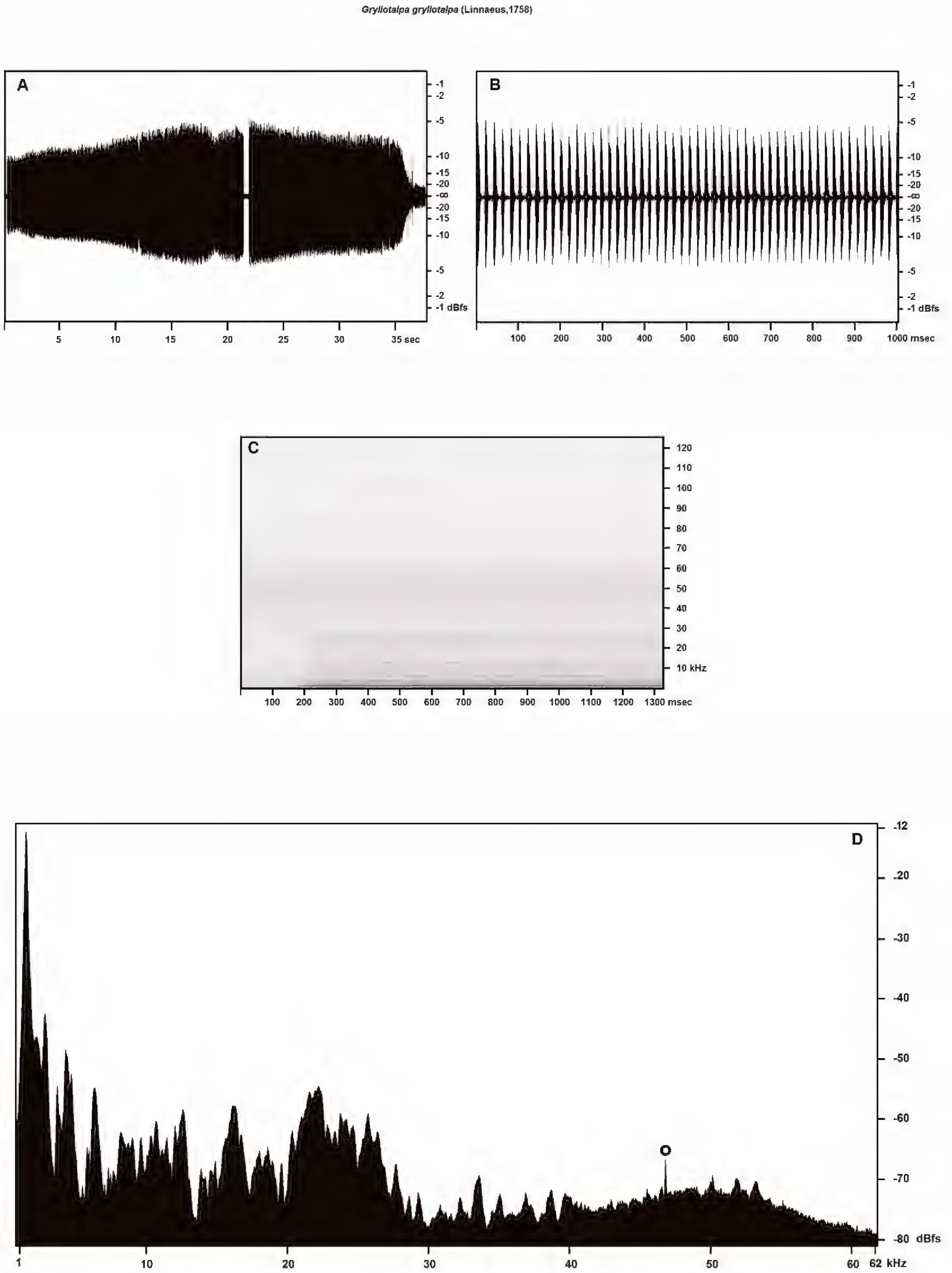


Figure 34. *Gryllotalpa gryllotalpa* (Linnaeus,1758) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 3.501 sec (see Table 3). A few artefacts peaks caused by the usage of 150cm USB cable with Ultramic 250 were eliminated with narrow band-stop filters as described in the text.

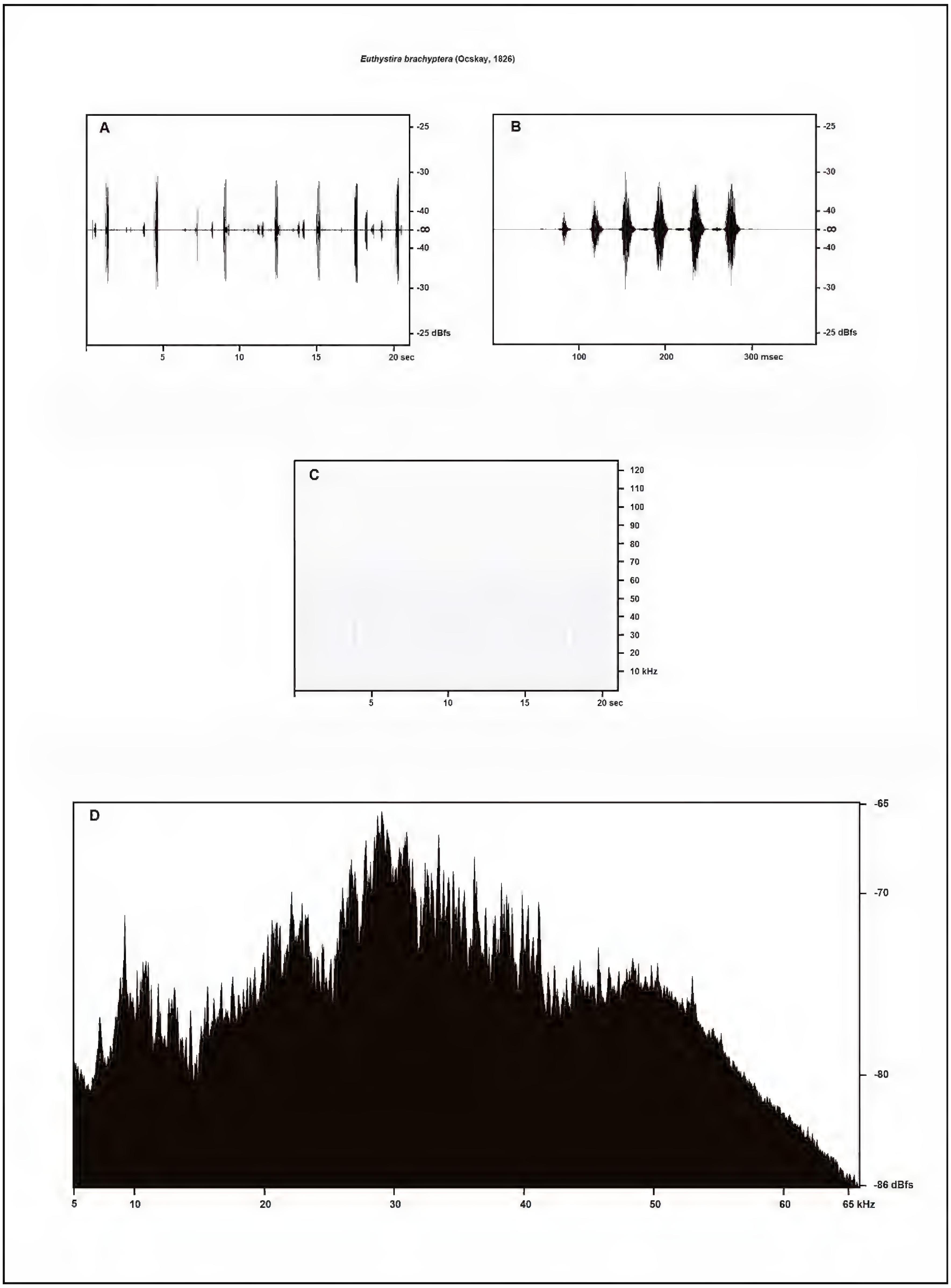


Figure 35. *Euthystira brachyptera* (Ocskay, 1826) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 11,683 sec (see Table 3).

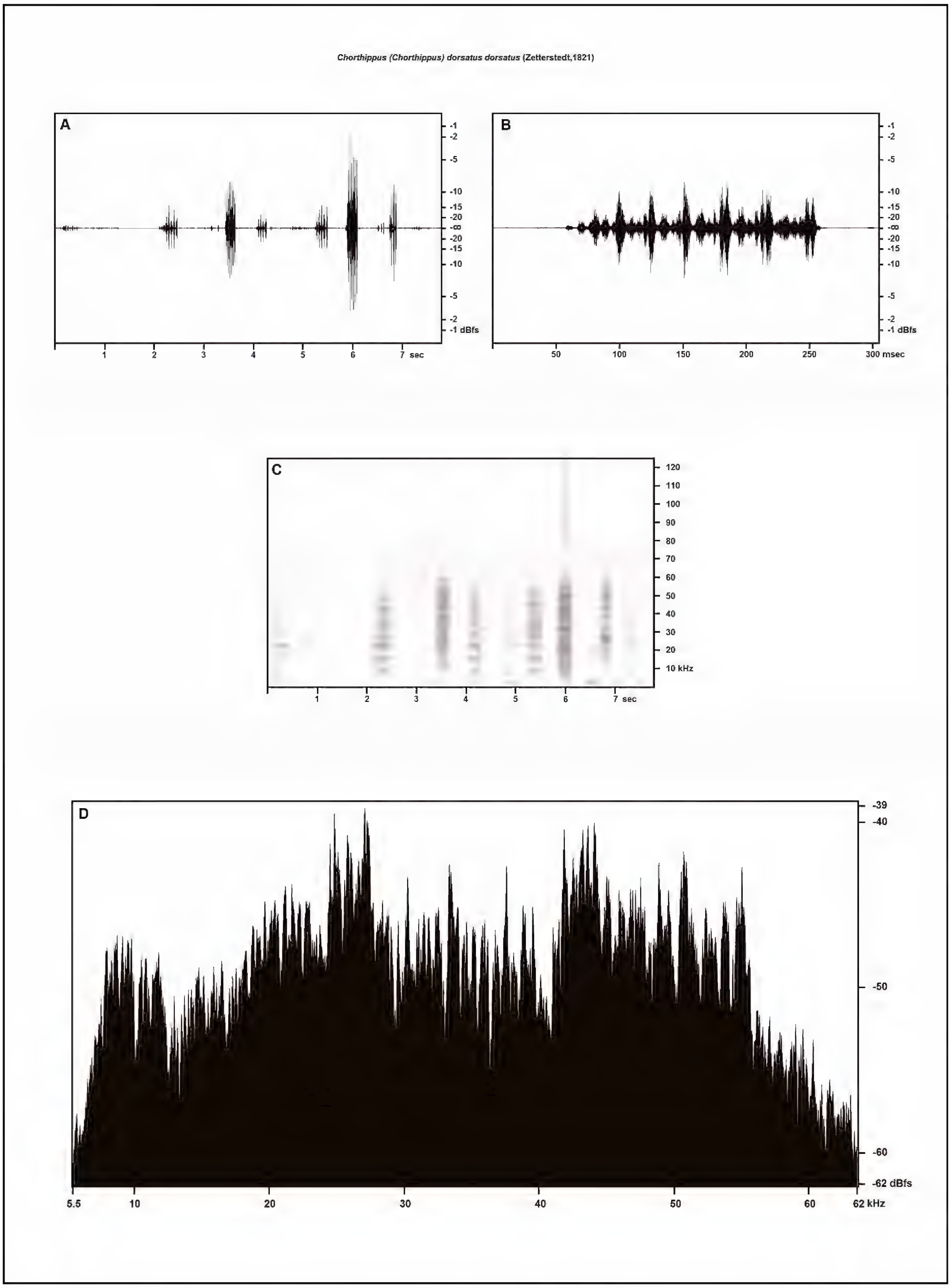


Figure 36. *Chorthippus (Chorthippus) dorsatus dorsatus* (Zetterstedt,1821) - A, B: envelope at two increasing levels of detail, C: spectrogram, D: frequency analysis - 0.501 sec (see Table 3).

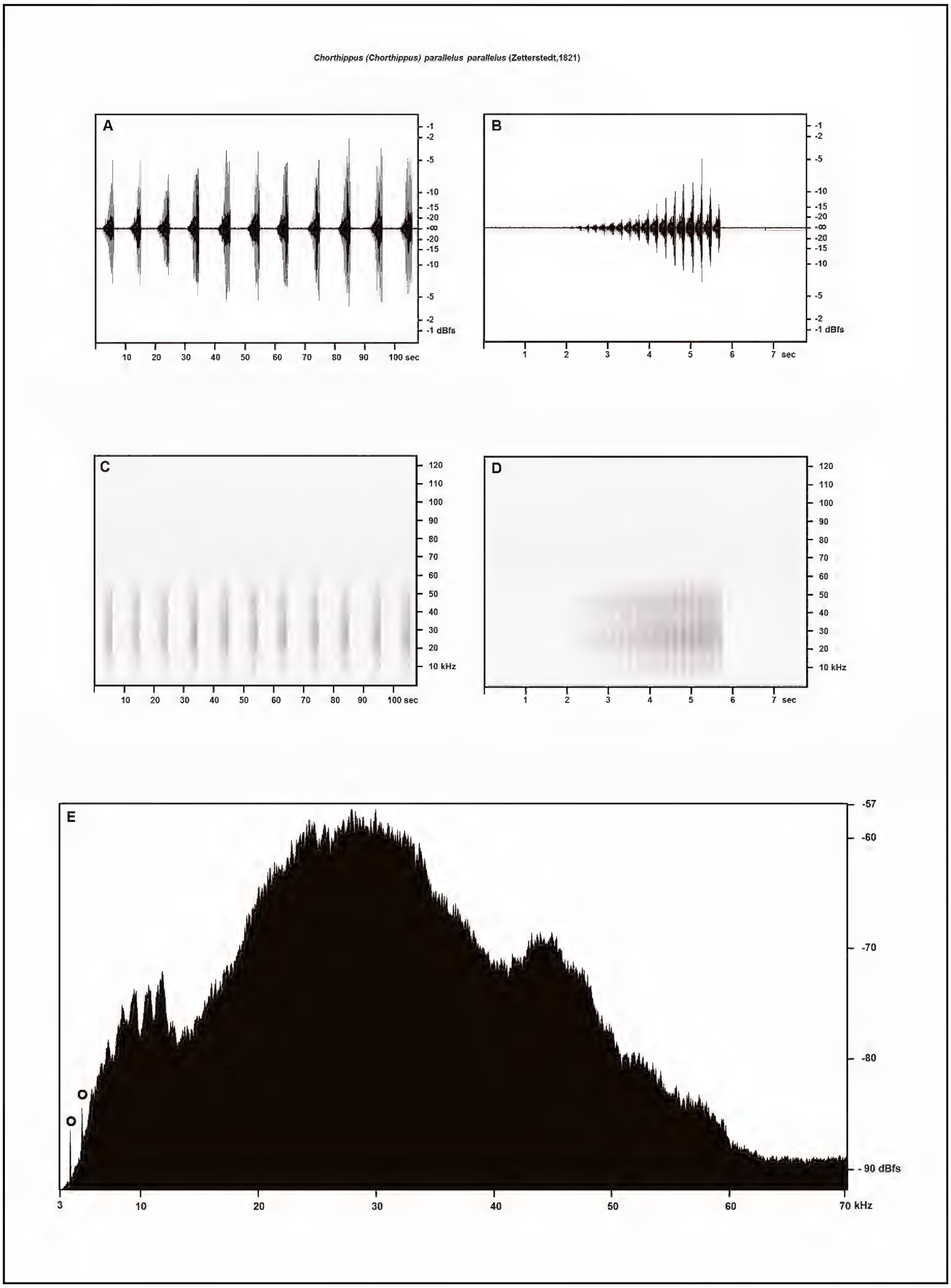


Figure 37. *Chorthippus (Chorthippus) parallelus parallelus* (Zetterstedt,1821) - A, B: envelope at two increasing levels of detail, C, D: spectrogram at two increasing levels of detail, E: frequency analysis - 14.825 sec (see Table 3).

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Supporting material

Available at the URL https:// bit.ly/2Mwt8gS includes 38 short excerpts (10 seconds or less) from 37 different species, provided for informative purposes. All the excerpts are extracted from the audio files used for song analysis, whose details are listed in Table 3. The initial number in the file name refers to the systematic order adopted in the paper and in the same table. Excerpts may be shorter portions of the analyzed samples, and in a few cases may not include the exact segment analyzed. The audio sample of *Tessellana tessellata tessellata*, less informative because of its extreme brevity, isn't included.

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Current situation of nitric pollution of irrigation water in the irrigated perimeter of F'Kirina (Algeria): extent and content

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ABSTRACT The plain of F'Kirina belongs to the sub-watershed of Garaet Tarf (Algeria). Its area is of the order of 760 km^2. The intensification of agriculture in this region leads to a significant use of phytosanitary products. The examination of the nitrate results on a low level of the measurements carried out on all the points of the plain of F'Kirina shows an area with a high concentration: near the salt lake Gareat Taref, the concentration of nitrates in the waters of irrigations are between 40 and 65 mg/l. In addition, in this zone, the water table is shallow, making the zone saturated with nitrate far exceeding the recommended standard, this mainly due to the presence of salt water. In the rest of the plain, the nitrate contents of the water remain in the standards of potability; they do not exceed 10 mg/l. These results confirm the impact of agricultural intensification in the degradation of the groundwater quality of the F'Kirina region.

KEY WORDS Agricultural pollution; Groundwater; Physicochemical parameters; Nitrates.

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INTRODUCTION

In recent years, the protection and conservation of natural environments, particularly water quality, has become a major concern and a major goal in development programs. Indeed, the increasing scarcity of national water resources and their deteriorating quality has led our country, in parallel with sustained efforts in water resources development and management, to pay special attention to the economy of the country and, mainly, in irrigation and control of all types of pollution.

Nitrogen is the most problematic element in agriculture. The highly soluble and mobile nitrates in the soil solution easily leach to the groundwater and thus constitute a potential source of pollution of the water table by nitrates (Soudi, 1995; Zoller, 1994).

The intensive cultivation of agricultural land in irrigated areas has led, in recent years, to the problem of pollution of groundwater resources by the nitrate ion. Concerns about this pollutant then increased, not only because of economic losses to the farmer or consequences on the health of the population, but also because of the complexity of the problem. Indeed, nitrates have a peculiarity that other pollutants do not have. They can be found in soil and water either as a result of fertilizer input, or as a consequence of natural biochemical processes that are closely dependent on regional pedoclimatic and ecological conditions.

In the irrigated perimeters of F'Kirina (Algeria), diffuse nitric pollution of groundwater decreases the potential of water resources of good quality, generates a health risk for the rural population and jeopardizes the socio-economic development of the country. Its mastery requires sufficient knowledge of the causes and mechanisms responsible for this pollution.

The deterioration of the quality of water resources constitutes a threat as important as that linked to the quantitative imbalance. Pollution continues to reduce the global balance of water resources and creates a risk for human health especially when it comes to the consumption of well water in rural areas where the majority of the population gets their supplies directly from the water aquifer (Id Ahmad, 1998).

MATERIAL AND METHODS

The chemical composition of water plays an important role in the determination of its quality, thus the possibility of its use for the supply of drinking water or other uses such as for irrigation.

The interpretation of the chemical composition of the waters makes it possible to compare the waters between them to explain the supply of the aquifers and its flow.

The physicochemical study of the groundwater of the F'Kirina plain is based on the sampling campaign conducted in 2015. The irrigation water samples were collected and transported to the laboratory within 24 hours following the sampling and analyzed to determine their physicochemical characteristics.

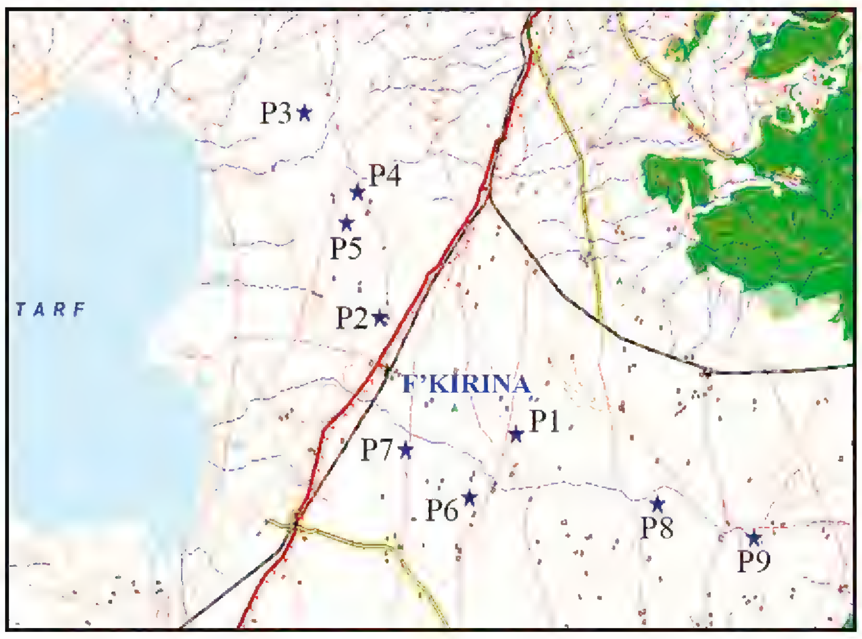


Figure 1. Geographical location of the sampling water points (F'Kirina, Algeria).

Sampling procedure

The purpose of the sampling is to collect a portion of water whose volume (500mL) is small enough to be transported easily but sufficiently representative for its analysis to demonstrate the characteristics of the entire equipment from which the sample is drawn. The sample must be handled in such a way that its composition is not altered during transport and all possible precautions must be taken to eliminate contamination or a change in sample composition caused by temperature or inadequate handling.

For sampling, at the beginning, the cold water must be allowed to run for 5 minutes at high flow before taking a sample to ensure that the water drawn is representative of that flowing through the distribution system. Then fill and rinse the bottle 3 times before proceeding with the actual sampling. When sampling, do not stick the neck of the bottle to the faucet to avoid contamination by metals. Fill the bottle to the brim to avoid the presence of air; and close the bottle tightly with the stopper.

The chemical analyzes were carried out at the water chemistry laboratory of ANRH in Constantine.

Location of water points

Nine operating wells exist in the study area (P1-P9). We had access only to water withdrawals, but not to piezometry, because there was no access to drilling. The spatial distribution of the wells and the source is shown in figure 1.

Statistical analysis of hydrochemical data

The statistical study of the data is essential to know the existing relations between the variables and the individuals as well as their spatial and temporal evolution. To achieve these goals, we opted for two studies: a) the first is preliminary, it concerns the elementary statistical study of the variables; b) the second one is more advanced, it is the Analysis in Principal Components (ACP) and treats the existing relations between the variables and the individuals as well as their spatio-temporal evolution.

RESULTS AND DISCUSSION

Elemental analysis

Descriptive statistical analysis of the data is presented in Table 1. This table shows that:

- the average conductivity of the water is 1. 59 ms/cm, but it shows a large difference between the different values with a standard deviation of 0.85 ms/cm and a range (maximum - minimum) of 2.4 ms/cm;
- the temperature of the water is mainly low (<20 ° C), averaging 17.7 ° C, this amounts to the fact that the boreholes capture deep aquifers, where the waters are not very influenced by the climatic changes;
- the pH is neutral to basic in all waters, indicating a release of CO2 or a combination of the latter with Ca2 + to form calcite. The range of pH changes is between 6.3 and 8.4.

The chemical elements have varying concentrations and can be divided into two groups:

- Low to medium concentration group: the element with the lowest concentrations is magnesium (Mg2+) with an average of 41.44 mg/l followed by sodium and potassium (Na ++, K+) with an average concentration of 56.04 mg/l, and lastly (NO3) with an average of 38.29 mg/l.
- High concentration group: it starts with sulfates (SO42-) with an average of 189.29 mg.

To find out the significant relationships, we used the Mangin formula (Mangin, 1974) to determine the threshold of good correlations R (relation N° 1):

$$R^2 = \frac{2}{\sqrt{n - 3}}$$

After calculation, we got R = 0.67, which implies that all correlations above 0.67 are good relationships.

These correlations show that the variations of the dissolved ionic charges are wholly or partly related to variations in the contents of these different ions. This also indicates that these different parameters tend to evolve concomitantly, by concentration under the effect of lithology.

They are shown in bold in the correlation table. This matrix shows:

- a good relationship between Na+ and Cl-, indicating that the origin of these two ions is halite (NaCl)
- a strong relationship between Mg++ and Cl- indicating that the origin of these two ions is MgCl (magnesium chloride).
- a strong relationship between Mg++ and SO42- indicating that the origin of these two ions is MgSO4 (magnesium sulphate: anhydrous salt).
- a good relationship between Ca++ and SO42- indicating that the origin of these two ions is CaSO4- (Gypsum).
- a good relationship between Ca and Cl indicating that the origin of these two ions is CaCl- (calcium chloride).

Variable	Comments	Comments with missing data	Comments without missing data	Minimum	Maximum	Moyenne	Extented	Ecart-type
TAC	9	0	9	1.64	4.50	3.54	2.86	0.91
HCO_3	9	0	9	100.04	274.50	202.50	174.46	47.96
Cl	9	0	9	60.35	495.25	197.26	434.9	140.63
SO_4	9	0	9	14.00	380.00	150.44	365.00	133.27
NO_3	9	0	9	3.70	65.00	37.44	61.30	21.72
DHT	9	0	9	6.00	20.60	10.29	14.60	5.17
Ca	9	0	9	120.24	244.49	153.23	124.25	44.25
Mg	9	0	9	10.00	126.95	34.75	115.19	37.54
Na	9	0	9	20.50	106.95	47.99	86.45	30.36
K	9	0	9	0.06	0.83	0.32	0.77	0.31
CE	9	0	9	0.77	3.17	1.40	2 .40	0.63
pH	9	0	9	6.30	8.40	7.01	2.10	0.91

Table 1. Descriptive statistical analysis of data.

TAC	1	0.88	-0.88	-0.64	-0.38	-0.84	-0.63	-0.88	-0.57	-0.52	-0.86	-0.68
HCO_3	0.88	1	-0.84	-0.42	-0.39	-0.72	-0.50	-0.82	-0.38	-0.34	-0.77	-0.68
Cl	-0.88	-0.84	1	0.79	0.34	0.95	0.81	0.94	0.74	0.76	0.98	0.74
SO_4	-0.64	-0.42	0.79	1	0.07	0.92	0.83	0.84	0.83	0.86	0.88	0.61
NO_3	-0.38	-0.39	0.34	0.07	1	0.27	0.38	0.17	0.02	0.08	0.29	0.19
DHT	-0.84	-0.72	0.95	0.92	0.27	1	0.89	0.94	0.76	0.80	0.98	0.68
Ca	-0.63	-0.50	0.81	0.83	0.38	0.89	1	0.70	0.58	0.74	0.83	0.36
Mg	-0.88	-0.82	0.94	0.84	0.17	0.94	0.70	1	0.77	0.72	0.96	0.82
Na	-0.57	-0.38	0.74	0.83	0.02	0.76	0.58	0.77	1	0.96	0.81	0.61
K	-0.52	-0.34	0.76	0.86	0.08	0.80	0.74	0.72	0.96	1	0.82	0.46
CE	-0.86	-0.77	0.98	0.88	0.29	0.98	0.83	0.96	0.81	0.82	1	0.75
pH	-0.68	-0.68	0.74	0.61	0.19	0.68	0.36	0.82	0.61	0.46	0.75	1

Table 2: Establishment of the correlation matrix between the 12 variables and based on the 23 individuals. Note: TAC: complete alcalimetric title, DHT: Tolerable weekly dose, CE: Electrical conductivity.

Parameter	**HCO_3 (mgl)**	**Cl (mgl)**	**SO_4 (mgl)**	**NO_3 (mgl)**	**DHT (meq)**	**Ca (mgl)**	**Mg (mgl)**	**Na (mgl)**	**K (mgl)**	**CE ms/cm**	**PH**
P1	201.3	106.5	15	40	6.6	122.23	11.76	23.46	0.065	0.77	6.3
P2	274.5	134.9	250	3.7	10	160.32	23.76	80.73	0.715	1.28	6.5
P3	100.04	495.25	380	43	20.6	200.4	126.95	106.95	0.825	3.17	8.4
P4	201.3	266.25	120	65	10.4	164.39	26.16	66.7	0.533	1.62	7.1
P5	176.9	330.1	300	60	17	244.49	57.24	44.37	0.477	2.17	6.9
P6	246.44	60.35	135	52	7.2	120.24	14.16	35.88	0.093	0.84	7.2
P7	211.06	152.65	125	4.3	8.8	125.86	30	31.52	0.084	1.12	7.2
P8	201	99	15	35	6	120.3	10	21.8	0.059	0.8	6.4
P9	210	130.3	14	34	6	120.8	12.7	20.5	0.063	0.82	7.1

Table 3. Average values of the physicochemical parameters of each well analyzed.

- an inverse relation between HCO3- and Mg2+, indicating the possibility that the water crosses the two geological formations (halite and carbonates);

- a good correlation of Mg+ and Cl- with salinity and conductivity.

The average values of the physicochemical parameters of each well are presented in Table 3.

Figures 2 and 3 show that the highest values are that of Ca++, NO3 and Cl-, which exceed the standards of Algerian potability.

The variations of dissolved salts make it possible to distinguish the two sources of salinization from water (Table 3). The waters of wells P3 and P5, with very high levels of chloride and notable sodium, are contaminated by salt lake.

Except for the wells P1, P8 and P9, the rest of the waters indicate a high contamination by the salts of the evaporites, in particular the wells P3 and P5, with considerable contents of sulphates and calcium.

Calcium, magnesium and sodium are the most common cations in surface and groundwater. They depend mainly on the geology (deposits of carbonates or gypsum present, etc.).

Nitrates are important to follow. Indeed, found in excess, they are an indisputable marker of pollution. At the level of the studied waters, the average concentration of nitrates is of the order of 35 mg/l which complies with the norm of 50 mg/l fixed by the WHO (O.M.S, 1986), in terms of potability.

High values were recorded in the center of the plain. This deterioration of the quality of these three wells (P4, P5 and P6) by nitrates could be attributed to point and dispersal releases of livestock products and the use of chemical fertilizers and pesticides related to agricultural activities, which then infiltrated through the soil to the water table. Although nitrates have no direct toxic effects except at high doses, they are readily converted by bacterial reduction into nitrites, the health effects of which would not be neutral (Elbouqdaoui et al., 2009).

Principal component analysis (APC)

The projection of the 12 variables and 23 individuals, by principal component analysis, on axes 1 and 2 is presented in the three figures 4, 5 and 6.

The projection of the variables shows that the axis 1 presents the salinity with two poles:

-The first proportional to salinity: it is presented by the proportional correlations between Mg+ and Cl; NO3, EC, SO4, Na, K and pH; salinity, conductivity and Ca2+. Indicating that the salinity of waters is related to both the dissolution of MgCl2 and (NaCl2) and the gypsum formations (CaSO4).

Ca2+ and SO4-2 have strong relations, and it can be related to the fact that the calcium comes at the same time from the dissolution of the limestones and the gypsum.

The projection of the individuals shows that this salinity is mainly linked to the wells P3, P4 and P5 by MgCl2.

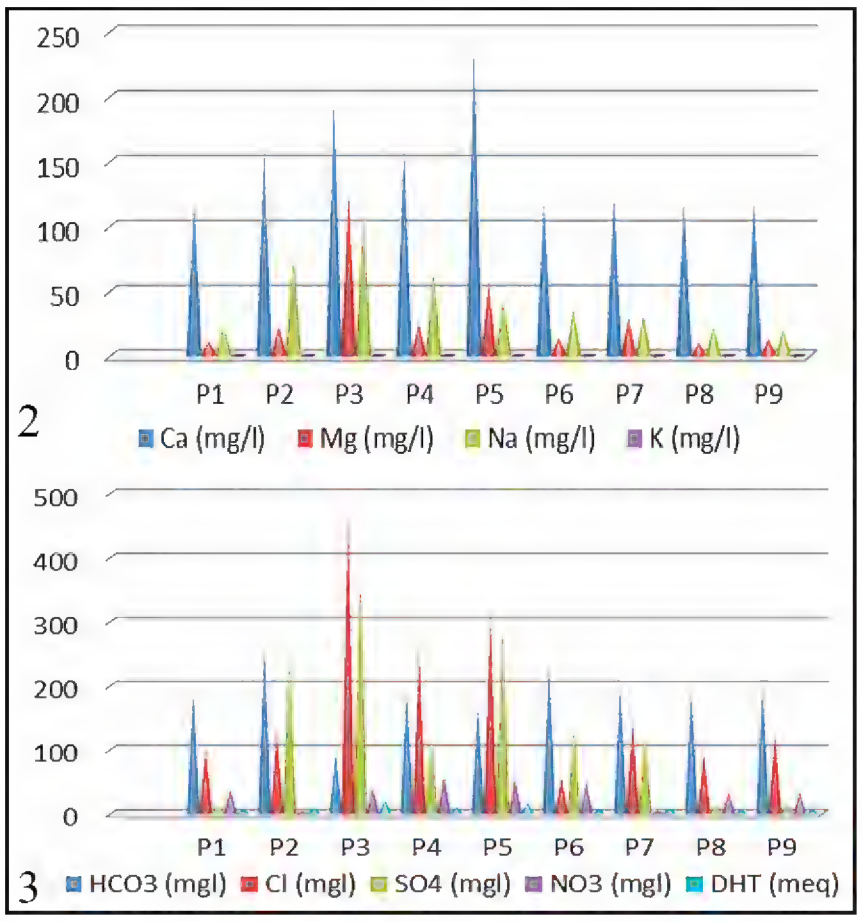
- The second has an inverse proportion to salinity and is represented by bicarbonates. The latter has an inverse relationship with nitrates.

Individuals with this cluster are: P2, P1, P6 and P7.

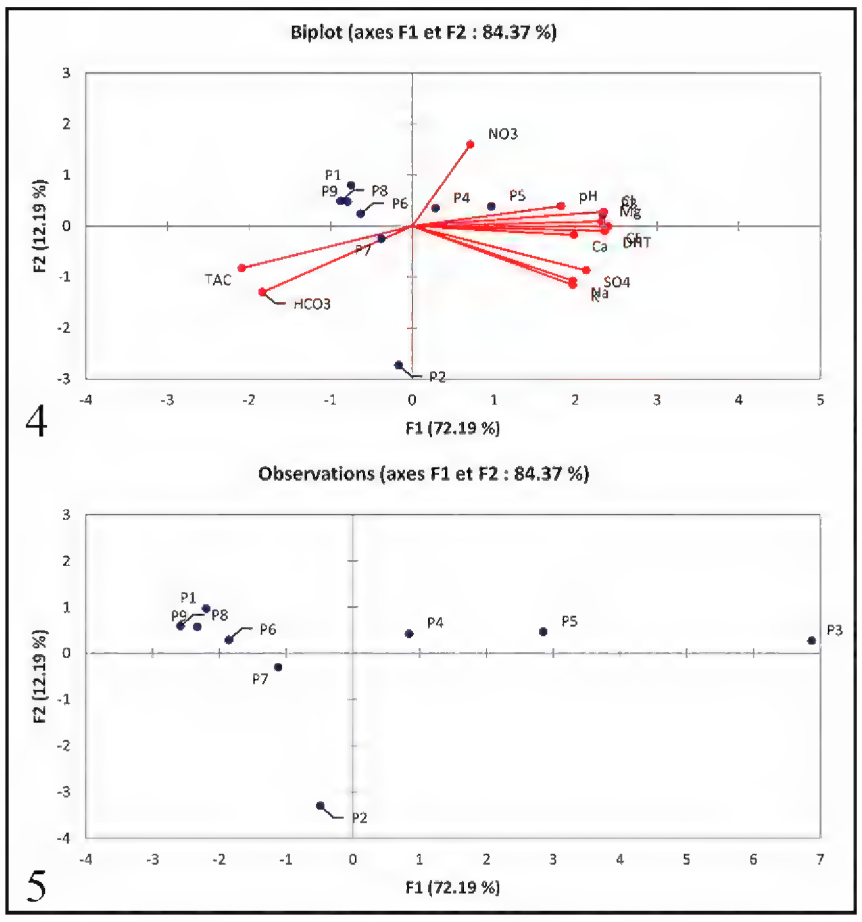
Chemical facies of waters

To determine the chemical facies of the water and its evolution over time, we used two diagrams: Piper diagram and Schoeler-Berkaloff diagram.

The Piper diagram (Fig. 7) shows the chemical facies of a set of water samples. It is composed of two triangles to represent the cationic facies and the anionic facies and a rhombus synthesizing the global facies. The principle consists in representing in each equilateral triangle the quantities in reaction with respect to the total concentration of the anions and the cations, one thus obtains two representative points indicating the dominance of an anion or a cation.



Figures 2, 3. Physicochemical parameters of irrigation wells of cations (Fig. 2) and anions (Fig. 3).



Figures 4, 5. Projection of Variables and Individuals on Axes 1 and 2 (APC).

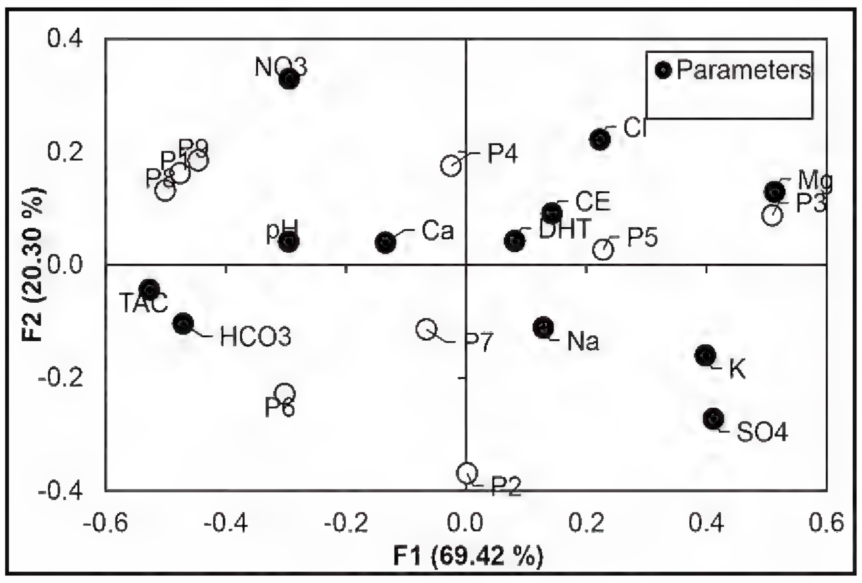


Figure 6. Symmetrical graph.

The composition of the water can be represented on the rhombus by a single point corresponding to the intersection of the parallels from these two points to the sides of the rhombus representing the chemical nature of the sample.

This diagram shows that the chemical facies of the waters is hyper-chlorinated calcium and hyper-sulphated calcium. Calcium hyperchloride facies is represented by the following wells: P3, P4, P5, P7, P8 and P9.

These diagrams show that the temporal evolution of the wells presents a gradual transition of water from sodium chlorides and potassium or sodium sulphated facies towards the hyperchloride sodium facies. This indicates an increase in chloride inputs Calcium of evaporitic origin (halite).

The Schoeller-Berkaloff diagram (Fig. 8) shows the chemical facies of several waters. Each sample is represented by a broken line. The concentration of each chemical element is represented by a vertical line in logarithmic scale. The broken line is formed by connecting all the points representing the different chemical elements. When the lines intersect, a chemical facies change is highlighted.

This diagram confirms that the most abundant ions are chlorine and calcium and sodium, and the least abundant chemical element is magnesium (Hillel, 1984).

The chemical quality of the water has a direct impact on farmland yield and soil conservation. For this purpose and given that the study area is agricultural, a chemical study of water for irrigation is essential to highlight the danger that certain chemical elements may present for plants and soils.

In order to appreciate the agricultural value of a solution, Wilcox (1949) proposed the first diagram delineating classes based on total mineralization and the percentage of sodium absorbed by water; then in 1954 the salinity laboratory of the US Department of Agriculture (Richards) proposed a second diagram also delineating classes based on total mineralization and sodium absorbed by soil (S.A.R).

The danger of alkalization is expressed by the value of the SAR, which is expressed as relation N° 2:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} \;+\; Mg^{++}}{2}}}$$

Ca++, Mg++ and Na+ are expressed in (meq/l).

This classification was proposed by Richards. It is very useful and reliable for characterizing irrigation water. Water loaded with salts can cause a risk for irrigation. This risk is determined using the Sodium Absorption Ratio (SAR) value. This parameter is a determination of the exchange capacity of Ca2+ ions, Mg2+, by Na+ in clays and colloids.

The SAR does not take into account changes in the Ca++ content of soil water occurring by precipitation or dissolution during or after irrigation. Sodium, which is an important factor in salinity, remains constantly soluble and in equilibrium with exchangeable sodium.

External agents have little influence on the dissolution or precipitation of sodium, whether it is concentrated by sampling the plant between two waterings, diluted by water applied or leached by drainage.

Sodium is an element of alkaline and alkaline earth bases. Given the heterogeneous nature of the soils, the relative proportions of Ca, Mg, Na are the main factors of the Sodium Adsorption Rate (SAR). If irrigated soils are supersaturated with sodium, the groundwater is contaminated by the effect of water return. Indeed, the cationic exchanges that take place in clays enrich the soils with salts (soils with crusts). This type of salinization affects semi-arid regions (Rodier, 1978).

Irrigation water quality is assessed using the U.S.S.L. Water Classification Chart (1954). It is a double-entry table, with the conductivities on the abscissa and the SAR on the ordinate. However, the proposed diagram was modified by the addition of a 5th class based on electrical conductivity (Durand, 1958).

The report of the results on this diagram (Fig. 9) shows that the irrigation water of the F'Kirina plain belongs to class (C3S1). Generally, this class contains admissible water for the irrigation of crops tolerant to salts, on well-drained soils or good permeability and salinity should be controlled. Class C3S1 represents wells located northeast of the city of F'Kirina.

Generally, plants do not tolerate soils saturated with sodium. The Wilcox classification, based on electrical conductivity and sodium content in water, is expressed as a percentage. The representation of the different samples on this diagram allows the characterization of waters for their ability to irrigate (Fig. 10).

The representation of the different samples analyzed on the Wilcox diagram shows that the waters of the plains of the F'Kirina plain belong to the four classes; excellent, good, mediocre and bad.

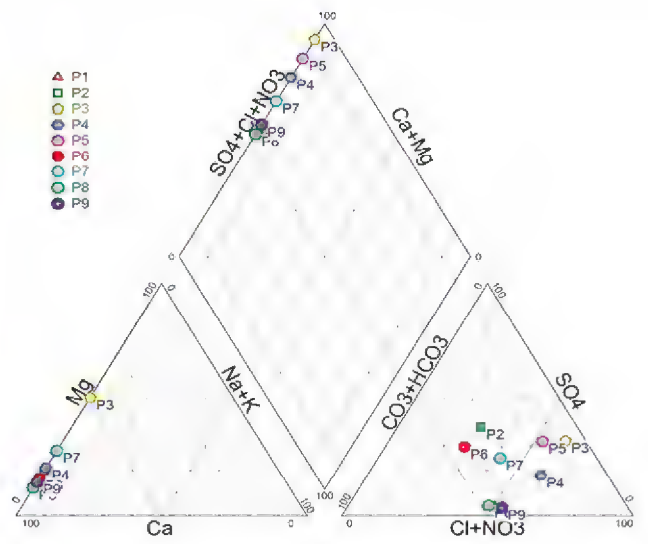
The poor quality waters are located in the center of the plain (near the salt lake) where the conductivities are high, since the waters in this place are salty and charged (P3 and P5). To the south and east of the plain the waters are of acceptable quality, and on the rest of the ground the waters present a good quality.

CONCLUSIONS

In this study, we assessed the quality of groundwater used in irrigation in the F'Kirina plain and also defined the current situation of nitric pollution. This issue is of great importance because of the problems in the region due to drought, the unavailability of surface water and the high demand from agricultural activities.

The hydrochemical study of the waters of the plain of F'Kirina allowed us to highlight several observations:

- the presence of four chemical facies marking the heterogeneity of the lithology. In fact, we could mention the bicarbonated facies characterizing the



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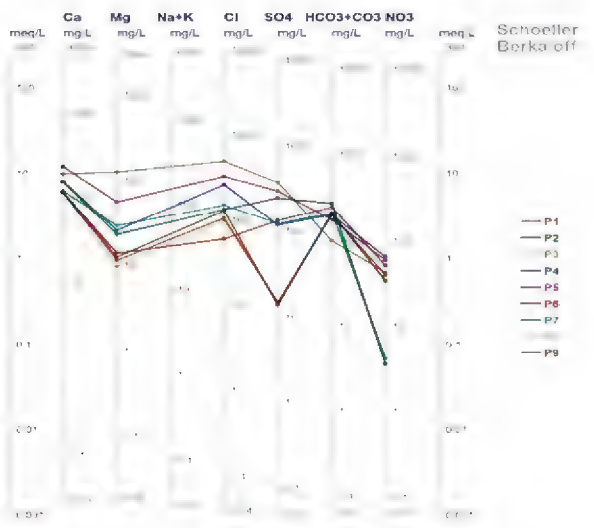

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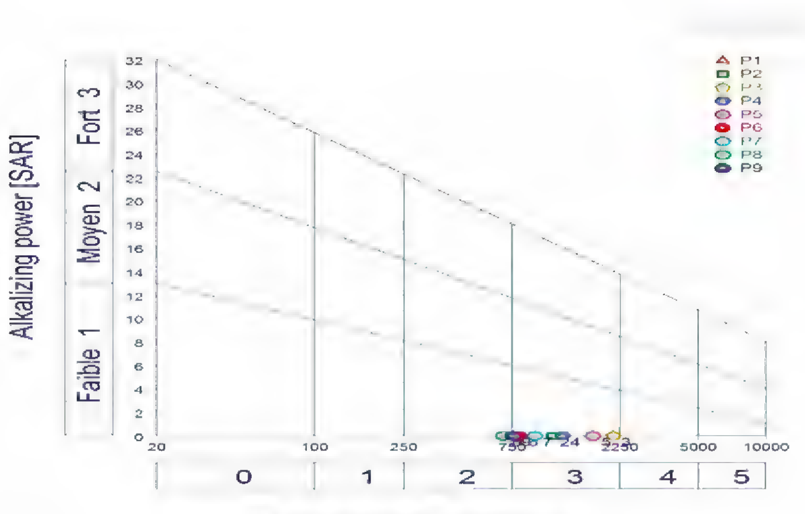
Figure 7. Representation of Piper Diagram in 2015. Figure 8. Schoeller-Berkaloff classification in 2015.



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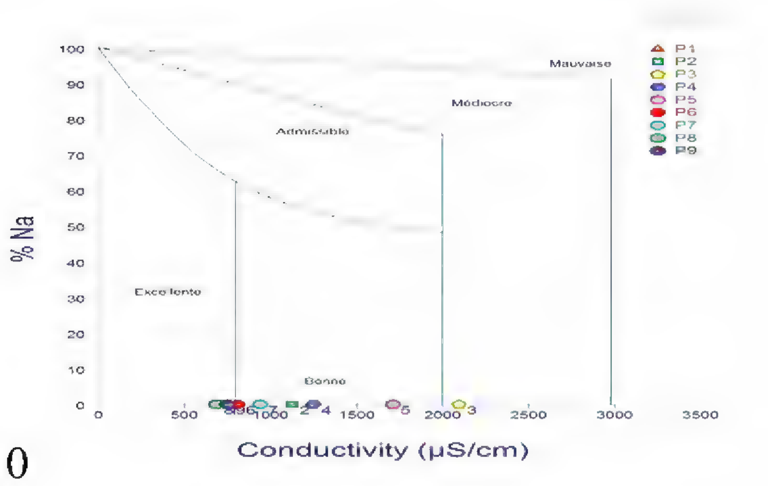

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Figure 9. Water classification according to S.A.R. (2015). Figure 10. Idem, according to the percentage of Na (2015).

water coming from the limestone margins, the chlorinated and sulphated facies resulting from the evaporitic formations and the salt facies, especially in the northern part of the aquifer;

- the spatial distribution of the chemical elements confirmed that the origin of these facies is strongly related to the lithological nature of the aquifer. The dissolution of carbonate and evaporitic formations is at the origin of this distribution.

The comparison of the concentrations of the chemical elements (Na+, Cl-, Ca2+, SO42-, HCO3) which characterize the main geological formations of the basin, highlighted the dominance of the salt ions ((Na+, Cl-) and the gypsiferous ions (Ca2+, SO42-) compared to those carbonates (Ca2+, HCO3-) in the acquisition of salinity.

Statistical analysis has shown that groundwater upstream of the aquifer is weakly mineralized and that downstream is highly mineralized.

The classifications of Richards and Wilcox showed the deterioration of water quality for irrigation.

In other words, there is much to confirm the existence of a significant contribution of intensive agricultural practices in the nitrate pollution of the groundwater of the plains of F'Kirina, and more particularly the nitrogen fertilization.

The choice of agronomic measures to combat nitric pollution of groundwater resources must be based on an assessment that compares, in terms of pollution reduction but also in terms of productivity, the measures envisaged. In addition, the control of groundwater pollution by nitrates could not be conceived without a program of sensitization of farmers and extension of adequate cultural practices to obtain good yields while respecting the nitric quality of groundwater resources.

The pollution of this groundwater with high doses of nitrates contained in its waters exposes the population of this region to the various types of intoxication that may result from the consumption of this water in the medium and long term. It is time that the public authorities and society as a whole act, so that we can take all the necessary steps to avoid an environmental catastrophe resulting in the deterioration of the health of the population. At the end of this study, we recommend:

- to install Hydrometric functional stations downstream of the plain near salt lake Gareat el Taref, to measure the liquid flows necessary for the determination of hydrological balance parameters;
- install piezometers near the boreholes in order to estimate the storage coefficient of the captured formations;
- control the use of fertilizers to avoid possible pollution by nitrates;
- reflection on the establishment of pollution vulnerability maps for the sensitivity of the aquifer of the studied region.

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Effects of environmental stress on the growth and the reproduction of *Perinereis cultrifera* (Annelida Polychaeta) from the eastern coasts of Algeria

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ABSTRACT Polychaetes tend to form the dominant sediment dwelling fauna of the most mudflats, estuaries and sheltered sandy shores and it also play a significant role in ecosystem functioning and services. Seasonal changes in the length, fresh weight, oocyte diameter, sexual status and sexual maturity index of the polychaete *Perinereis cultrifera* (Grube, 1840) (Anellida Polychaeta Nereididae) were studied during twelve months from January to December 2016 in the east coast of Algeria. The samples were collected monthly at three sites: El-Kala, a site far from any source of pollution, Annaba and Skikda, sites located near human and industrial wastes. The reproductive cycle of the females was studied; however, the ovaries consist of coelomic germ-cell clusters surrounded by a thin envelope of follicle cells. The female coelomic puncture has a heterogeneous aspect and shows different oocyte diameters. The reproductive period is more intense in spring period. The results show differences between sites compared with the reference samples. The reproduction period of occurs in spring (April, May). This approach confirms that individuals collected from Annaba and Skikda have been submitted to a highly polluted environment. Therefore, individuals sampled from Skikda showed the highest reduction of different measured parameters.

KEY WORDS Marine pollution; Reproduction; Ecology; Growth; Annelids.

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INTRODUCTION

The coastal marine environment is widely exploited for its economic wealth (fishing, mariculture) and tourism. The marine ecosystem suffers from several types of pollution; from direct discharges (municipal and industrial effluents, oil spills) and indirect discharges (riverine and atmospheric) (Rudolph & Rudolf, 1999). There are different types of chemical contaminants ranging from radioactive discharges (Uddin et al., 2015; Falfushynska et al., 2016), the nanoparticles (Rocha et al., 2015), organic materials (Olivares-Rubio & Vega-López, 2016), such as polychlorinated biphenyls (PCBs) (Choi et al., 2014; Kodavanti & Loganathan, 2017), and polycyclic aromatic hydrocarbons (PAHS) (Lüchmann et al., 2014; Guo et al., 2017), pesticides (Moraleda-Cibrián et al., 2015; El Nemr et al., 2016; López et al., 2017), the pharmaceutical products (Aguirre-Martinez et al., 2016; Andreu et al., 2016; Joseph, 2017), and the heavy metals (Chandurvelan et al., 2015; Schoonover et al., 2016; Durkalec et al., 2017).

The eastern Algerian coastline is the most important touristic and economic zone. It is continuously affected by various contaminants from urban, agricultural, harbor and industrial activities (Boucetta et al., 2016).

Benthic communities are directly exposed to contaminants adsorbed on the particle phase, but also to those dissolved in water at the sediment-water interface and, as a consequence, they have been conventionally used as bio-indicators in the biomonitoring of sediment toxicity (Lotufo et al., 2001). These communities are formed by a large majority of sedentary species which are integrator agents of temporal effects of various environmental stresses either of natural or arthropogenic origin. Polychaete annelids are well represented in marine environments and constitute a significant percentage of total biodiversity and abundance of benthic macrofauna. Polychaetes are the dominant macrofauna within fine sediments. (Fauchald, 1997). Polychaeta worms of the Nereididae family are one of the most common and representative species of estuarine macrobenthos (Scaps, 2002), and they are classified as key species due to their important role as a food source and in biogeochemistry processes (Banta & Andersen, 2003; Amiard-Triquet, 2009). Sustainability of estuarine environments is necessary to maintain the ecological and economic health of coastal regions. So, the assessment of key estuarine population species is ecologically relevant in the environmental assessment of estuarine areas. *Perinereis cultrifera* (Grube, 1840), type locality: Naples, Italy, has been regarded as a cosmopolitan species, recorded to be from the Atlantic Ocean, Yellow Sea, Mediterranean Sea, Red Sea, Arabian Sea, Indian Ocean and Pacific Ocean (Grube, 1840; Fauvel, 1932, 1936, 1953; Uschakov & Wu, 1965; Imajima, 1972, 1996, 2003; Paik, 1977, 1979, 1989; Wu et al., 1985; Hutchings et al., 1991; Miron et al., 1991; Fidalgo & Costa, 1999; Wehe & Fiege, 2002). The polychaete worms, as benthic fauna are biological parameters that indicate the overall aquatic fertility of the sediments, and the study of the polychaetes may be used as baseline information to evaluate the demersal fish stocks, as they form a major food item in the nutrition of the bottom feeders. In addition, and more importantly they could be used as good biological indicators of marine pollution.

Perinereis cultrifera is characterized by a monotelic (Semelparous) pattern of reproduction in which a single, climatic reproductive event is followed by death. The majority of studies on endocrine regulation of reproduction are related to neuroendocrinology aspects. Growth and gametogenesis are controlled by a neuro hormone produced by the cerebral neuroendocrine system. Neuroendocrine activity is high during the early stages of life; later reduces resulting in the accumulation of maturing gametes (Golding & Yuwono, 1994). Concerning oogenesis, four phases could be recognized: oogonia (active mitosis), premeiotic, previtellogenic and vitellogenic (Olive & Clark, 1978). When primary oocytes appear, they accumulate nutritive resources (lipids, glycoprotein and finally lipovitellin) and will grow until a maximum oocyte diameter. During the maturity of genital cell, rag worm *Perinereis cultrifera* show metamorphosis, including the enlargement of eye, seta and parapodia in the middle part to be modified as the swimming device. Many worms live in the base of waters, but swim into surface at night during spawning to release egg and sperm. The lenght changes during the development and it is difficult to correctly identify (Rouabah & Scaps, 2003b).

In this context, the aim of this study is to evaluate the impact of environmental pollution on the reproduction of females of *P. cultrifera* in considering a morphometric, overweight and biochemical study of three populations monthly sampled at three sites of the east coast of Algeria which have different levels of pollution.

MATERIAL AND METHODS

Study area

Sampling sites were chosen because of their geographical locations in eastern Algeria (Fig. 1). Site selection was based on the level of pollution as well as ease of access to the study area and abundance of species. El-Kala (36°53’44”N, 08°26’35”E) is close to the Tunisian border (10 km). This site is minimally influenced by anthropogenic inputs, given the low urbanization of the region. Moreover, there is a notable absence of industries and consequently, little or no industrial atmospheric or continental pollution (Ounissi & Khelifi-Touhami, 1999). Annaba

(36°54'27" N, 7°45'26"E) is located about 80 km from the Tunisian border. This site is a standout amongst the most vital vacationer and financial focuses on the eastern coasts of Algeria. It is considered as the receptacle for all residues, toxic or not, produced by the various industrial units located along the coast. Due to this, fishery stocks threatened by pollution are linked to the burgeoning economic activity. In addition, previous work has shown that the Annaba gulf region is influenced by metal-rich effluents and is subjected to agricultural, industrial and urban activities as well as tourism development (Semadi & Deruelle, 1993; Abdenour et al., 2000; Beldi et al., 2006; Sifi et al., 2007; Amira et al., 2011; Soltani et al., 2012; Sifi et al., 2013; Belabed et al., 2013b; Amri et al., 2017b). In addition, the port of

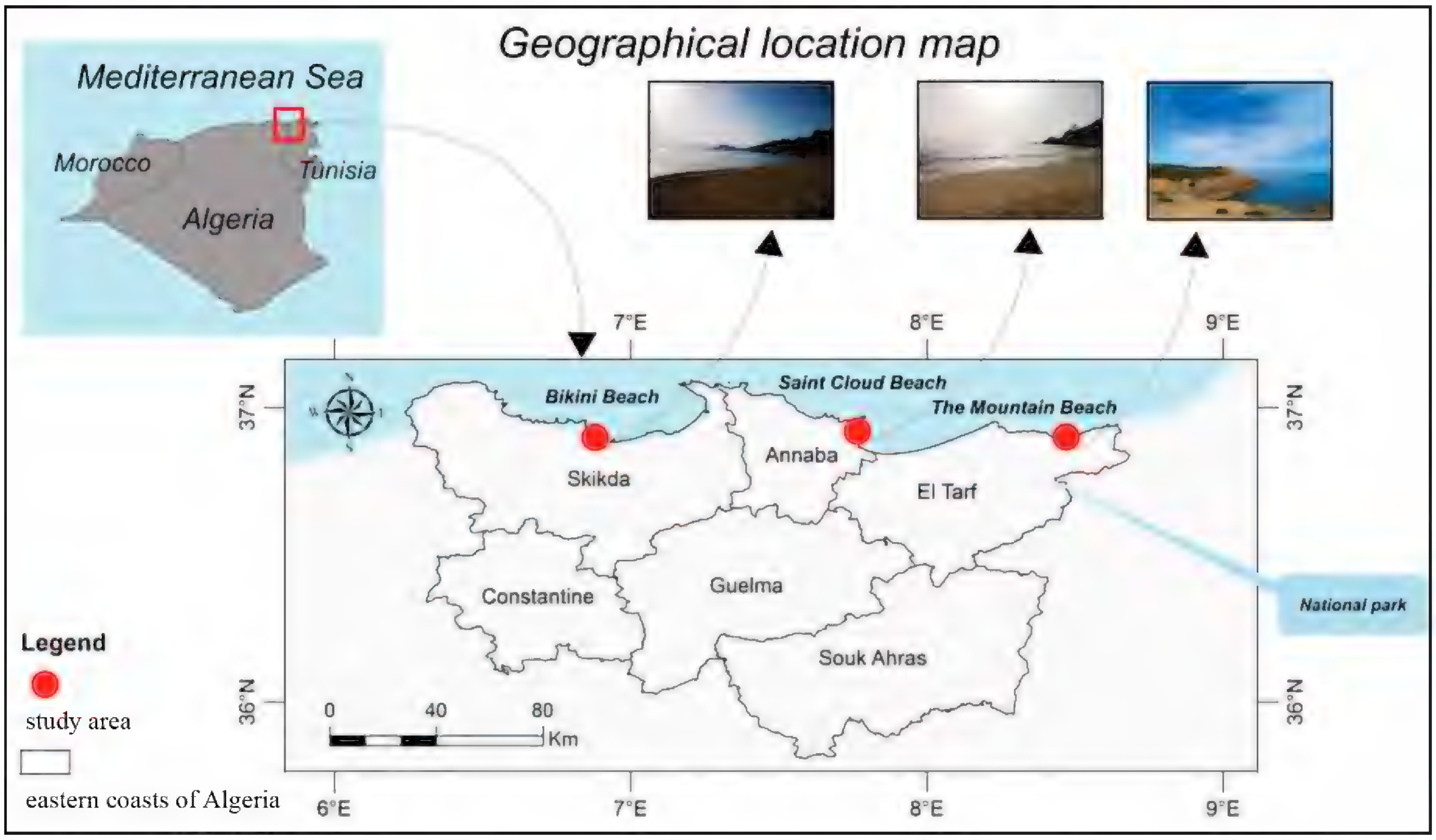

Geographical location map
Mediterranean Sea
Morocco
Tunisia
Algeria
7°E
8°E
9°E
37°N
Bikini Beach
Saint Cloud Beach
The Mountain Beach
Skikda
Annaba
El Tarf
Constantine
Guelma
Souk Ahras
National park
Legend
study area
eastern coasts of Algeria
0
40
80
Km
36°N
6°E

Figure 1. Map of eastern coasts of Algeria shows the three sampling sites of this study.

Posistion of sampling	**Geographic coordinates**	**Soil**	**Nature of the substrate**	**Pollution**	**Associated species encountered**
El-Kala (La Montagne)	36°53′53.33″N 8°27′3.28″E	Rocky	Dense	Unpolluted	*Perinereis macropus, Perinereis oliveirae, Nereis falsa, Lepidontus clava, Diodora graeca, Tricolia spesiosa, Eriphia verrucosa, Fascolosoma granulatum, Patella depressa, Amphipoda* sp., *Isopoda* sp., *Ulva lactuca, Corallina elongata, Colpomenia sinuosa*
Annaba (Saint-Cloud)	36°54′5.79″N 7°45′22.20″E	Rocky and Sandy	Dense	Urban and industrial	*Nereis falsa, Diodora graeca, Tricolia spesiosa, Eriphia verrucosa, Amphipoda* sp., *Ulva lactuca, Corallina elongata, Colpomenia sinuosa*
Skikda (Bikini)	36°52′18.86″N 6°54′3.28″E	Rocky and Sandy	Slender	Urban and industrial	*Nereis falsa, Nereis fucata, Diodora graeca, Tricolia spesiosa, Eriphia verrucosa, Amphipoda* sp., *Ulva lactuca, Corallina elongata, Colpomenia sinuosa*

Table 1. Characterization of sampling sites.

Annaba receives 9% of the polluting load (NWSEP/PNAE-DD, 2002). Skikda (36°4'0"N, 06°49'60"E) is located about 180 km from the Tunisian border. This site is near from Storaport that is characterized by an intense maritime traffic. This site is exposed to the pollution by PAH due to the presence of an important petrochemical complex (Abdenour, 2000; Bordjiba et al., 2009; Guemouda et al., 2014).

The choice of study sites was based on the sites accessibility, the abundance of the species and the sampling ease.

Sampling procedure

Specimens were collected monthly from January to December 2016. They were found within Rhodophyceae, in algal-covered hard bottoms. They live in the low intertidal zone and extend down into the sublittoral; in consequence, the intertidal and shallow sublittoral hard bottoms were sampled methodically by scraping algae and looking for individuals (Rouabah & Scaps, 2003).

Abiotic parameters

The following parameters were measured monthly *in situ*: temperature (T), salinity (S), pH and dissolved oxygen (O_2) using a multiparameter-oxymeter (Multi 340i/SET) at each site monthly from January 2016 to December 2016

Morphometric measurements and sexual differenciation

The samples were prepared and weight, length and the setigeres were measured. Worms were weighed individually at one-tenth of mg after drying on paper filter. Sex and the state of maturity has been determined on all harvested individuals. Microscopic examination of the body content allowed to recognize males, females and individuals undifferentiated and therefore to determine monthly percentages corresponding to each sex. The state of epitokous has been estimated from observation under the microscope of Parapodia taken in medium-sized and terminal areas.

At each sampling date, the following variables were measured: total lengh (TL), fresh weight (FW), percentage of sexual individuals and oocyte diameter (OD).

Examination of coelomic punctures and oocyte examination

To study the reproductive cycle, the individuals were fixed in the laboratory with 8% neutral formaldehyde and examined for the presence of sexual products in the coelom. A short incision was made in the body wall at about the twentieth chaetigerous segment and a drop (~ 1 ml) of the coelomic fluid was removed with a Pasteur pipette and examined under a binocular microscope (Fig. 2). When possible, forty oocytes were measured using a calibrated eye piece graticule. The longest and the shortest diameter of oocytes were determined, and the average value was used as an estimate of oocyte size.

Size-frequency distribution of oocytes

The diameter of at least 100 oocytes was measured using a calibrated eyepiece graticules and consisted of coelomic germinal clusters surrounded by a thin envelope of follicle cells derived from the peritoneum.

Sexual maturity index (SMI)

Since sex-ratio (about 80%) is greatly in favour of females, investigation was carried out only on female worms.

In order to determine worm's sex and to assess sexual maturity of females, an incision using a scalpel approximately 30 segments behind the head was realized. The segment content was released on a glass slide and the coelomic fluid was examined under microscope. The dimension measured was maximum diameter of each oocyte to the nearest micrometer. Reproductive status of specimens was characterized by a stage of maturity ranging from 1 to 4 (Table 1). Then, a sexual maturity index (SMI) was calculated as:

$$SMI = [(1^* n1) + (2^* n2) + (3^* n3) + (4^* n4)]/N$$

Where nx is the number of individuals in stage x and N the sum of nx (Durou & Mouneyrac, 2007).

Statistical analysis

Data were expressed as means ± standard deviation (M ± SD). The normality of the distribution was tested using the Shapiro-Wilk test. To assess multiple comparisons, a parametric one-way analysis of variance (ANOVA) was performed on data with a Tukey's test. All statistical analyses were performed using MINITAB Software (Version 14, PA State College, USA) and statistical significance was defined at the $p < 0.05$ level. The correlations between different parameters were determined by using Speerman-test.

Seasonal and intersite variation of parameters by Principal Component Analysis (PCA)

The use of Principal Component Analysis (PCA) as a preliminary and exploratory descriptive approach made it possible to visualize the structuring of the temporal and spatial variation at the three sites according to eight variables: water temperature (T), pH, salinity (Sal), dissolved oxygen (Oxy), length (L), fresh weight (FW), oocyte diameter (OD) and sexual maturity index (SMI).

RESULTS

Environmental characterization

The seasonal variations in the physicochemical parameters of the water are represented in Table 2. The results show that changes in the physicochemical parameters are directly related to seasonal rhythm; the lowest temperatures are recorded during winter whereas during spring, the temperatures show an appreciable increase, with a maximum in summer. The ANOVA single controlled factor variance analysis indicates that there are significant differences only between the dissolved oxygen in

Season	Site	Temperature (°C)	Salinity (mg/l)	Oxygen dissolved (mg/l)	pH
Winter	S1	**13.93± 1.15**	**32.96 ± 3.07**	**8.60 ± 0.26**	**8.06 ± 0.55**
	S2	**13.26 ± 1.02**	**31.36 ± 1.20**	**8.36± 0.32**	**8.12 ± 0.68**
	S3	**13.20 ± 1.15**	**32.33 ± 2.40**	**6.83 ± 0.56**	**7.83 ± 0.72**
P Value		**0.689**	**0.718**	**0.004****	**0.828**
Spring	S1	**17.53 ± 1.26**	**33.70 ± 1,80**	**7.73 ± 0.60**	**8.20 ± 0.26**
	S2	**17.13 ± 1.45**	**34.33 ± 1.70**	**6.90 ± 0.20**	**8.00 ± 0.50**
	S3	**17.12 ± 1.72**	**34.56 ± 0.85**	**6.50 ± 0.43**	**8.53 ± 0.20**
P Value		**0.932**	**0.778**	**0.037***	**0.244**
Summer	S1	**25.93 ± 1.80**	**36.86± 0.20**	**6.46 ± 0.21**	**8.36 ±0.15**
	S2	**24.66 ± 1.15**	**36.80 ± 0.26**	**5.06 ± 0.26**	**8.13 ± 0.37**
	S3	**25.10 ± 1.73**	**36.76 ± 0.15**	**3.90 ± 0.55**	**8.10 ± 0.26**
P Value		**0.635**	**0.847**	**0.000*****	**0.491**
Automn	S1	**19.66 ± 0.85**	**32.53 ± 1.35**	**7.70 ± 0.20**	**8.13 ± 0.20**
	S2	**19.83 ± 0.68**	**32.50 ± 1.08**	**6.17 ± 0.32**	**7.83 ± 0.21**
	S3	**19.13± 0.66**	**33.43 ± 0.25**	**5.60 ± 0.70**	**7.93 ± 0.30**
P Value		**0.517**	**0.484**	**0.003****	**0.373**

Table 2. Seasonal variations of physicochemical parameters analyzed at the 3 sampling sites, El-Kala (S1), Annaba (S2) and Skikda(S3), from winter to autumn 2016

the three study sites ($P < 0.05$) and specially in summer.

Annual evolution of the size length

The morphometric measurements show that the female individuals collected from El-Kala site (La-Montagne) have the highest values followed by the individuals collected from the Annaba site (Saint-Cloud) and the Skikda site (Bikini). The maximum length was 50.03 ± 3.99 mm in April for females individuals collected at the site of El Kala (La Montagne) and the minimum length was 19.68 ± 1.97 mm during August concerning the collected individuals at the Skikda (Bikini) site. Usually, the month-length variation regarding females of *P. cultrifera* at the sites studied shows that the individual's length increases from February and reaches a maximum value in April at the level of all sites studied, followed by a decrease in size during the two months of July and August and then gradually increase from September in the three study sites.

The variance analysis of the monthly variations in length by the Tukey test makes it possible to compare the different averages and to classify the studied sites into two groups during the months of January, June and July. Group A includes the El-Kala site (La Montagne), and Group B includes the two sites Annaba (Saint Cloud) and Skikda (Bikini).

The Tukey test classified the studied sites into two groups during the months of September, October and November; group A contains the two sites El-Kala (La-Montagne) and Annaba (Saint Cloud).

The test reveals three groups during the months of February, March, April and August. Group A corresponds to the El-Kala site (La Montagne) where the average values of length are the highest, Group B contains females from the Annaba site (Saint Cloud) which have female lengths between El Kala (La Montagne) and Skikda (Bikini), and Group C corresponds to the Skikda site (Bikini) that represents the minimum values (Fig. 2).

In addition, the Tukey test made it possible to classify the studied sites into three groups during the month of December. Group A includes the El-Kala site (La Montagne), group AB represents the Annaba site (Saint Cloud), and group B includes the Skikda site (Bikini).

The one-way ANOVA tests show that there is a highly significant difference during the month of December ($p = 0.008$), as well as very significant differences between the sites ($P = 0.000$) during the months of January, February, March, April, May, June, July, August, September and October. The two-ways ANOVA tests (month, site) exhibited that there is a very highly significant effect between months and between sites and also a very highly significant site/month interaction ($P<0.001$) (Fig. 2).

Annual evolution of fresh weight

The monthly variations in fresh weight of *P. cultrifera* females show a gradual increase in January weight with a maximum reached in April (0.305 ± 0.05; 0.242 ± 0.074 and 0.186 ± 0.06 g), respectively, for the sites of El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikini), then a decrease in weight reaching a minimum in August (0.092 ± 0.03; 0.074 ± 0.02 and 0.068 ± 0.03 (g) in El-Kala (La-Montagne), Annaba (Saint Cloud) and Skikda (Bikini), respectively, and a slight increase in December was recorded (Fig. 3).

Analysis of the monthly variation in body weight of *P. cultrifera* females using the Tukey test allows to compare the averages in order to classify the studied sites into three groups during the months: August, September and December; group A includes the individuals from El-Kala (La Montagne) that have the highest weight values, group AB represents the individuals from the Annaba site (Saint-Cloud) whose weight is not different from that of the individuals from the El-Kala site (La-Montagne), group B includes the individuals from the Skikda site (Bikini) that have the lowest values.

The Tukey test allowed us to classify the sites into two groups for the months of January and July: group A representing the site of El-Kala (La Montagne), group B corresponding to the two sites of Annaba (Saint-Cloud) and Skikd (Bikini). This indicates the existence of a notable difference between the females of El-Kala (La Montagne) and those of the other sites while within the same group B there is no difference.

The test highlights two groups during the months: February, March, May, June and November, group A contains the individuals from El-Kala (La Montagne) and Annaba (Saint-Cloud) where the weight is higher, group B includes the individuals from the Skikda site (Bikini), which has the lowest individuals. The Tukey test made it possible to classify the

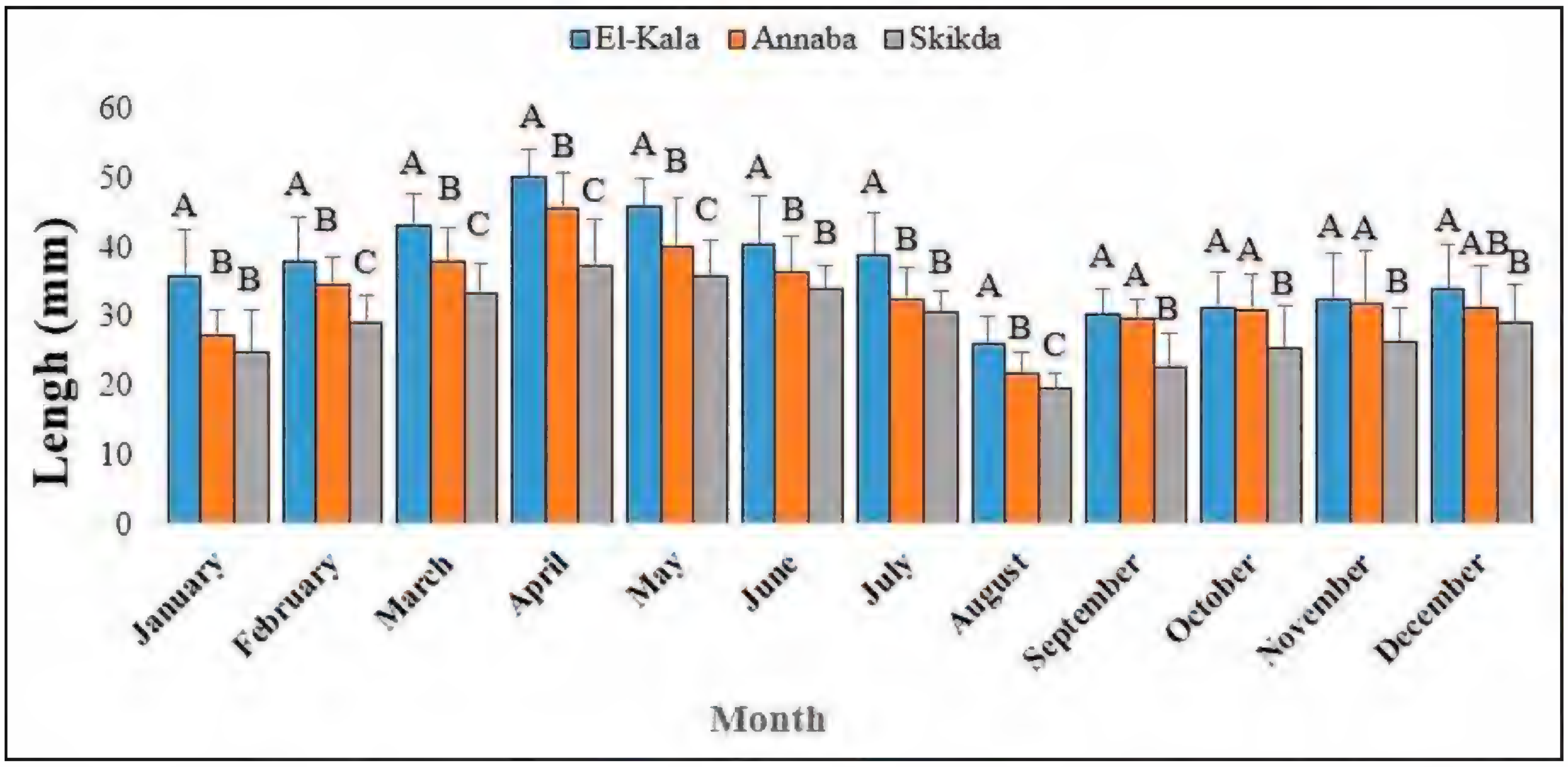


Figure 2. Monthly length variations (mm) in females of *Perinereis cultrifera* at the three study sites: El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikini) during 2016 (Tukey classification).

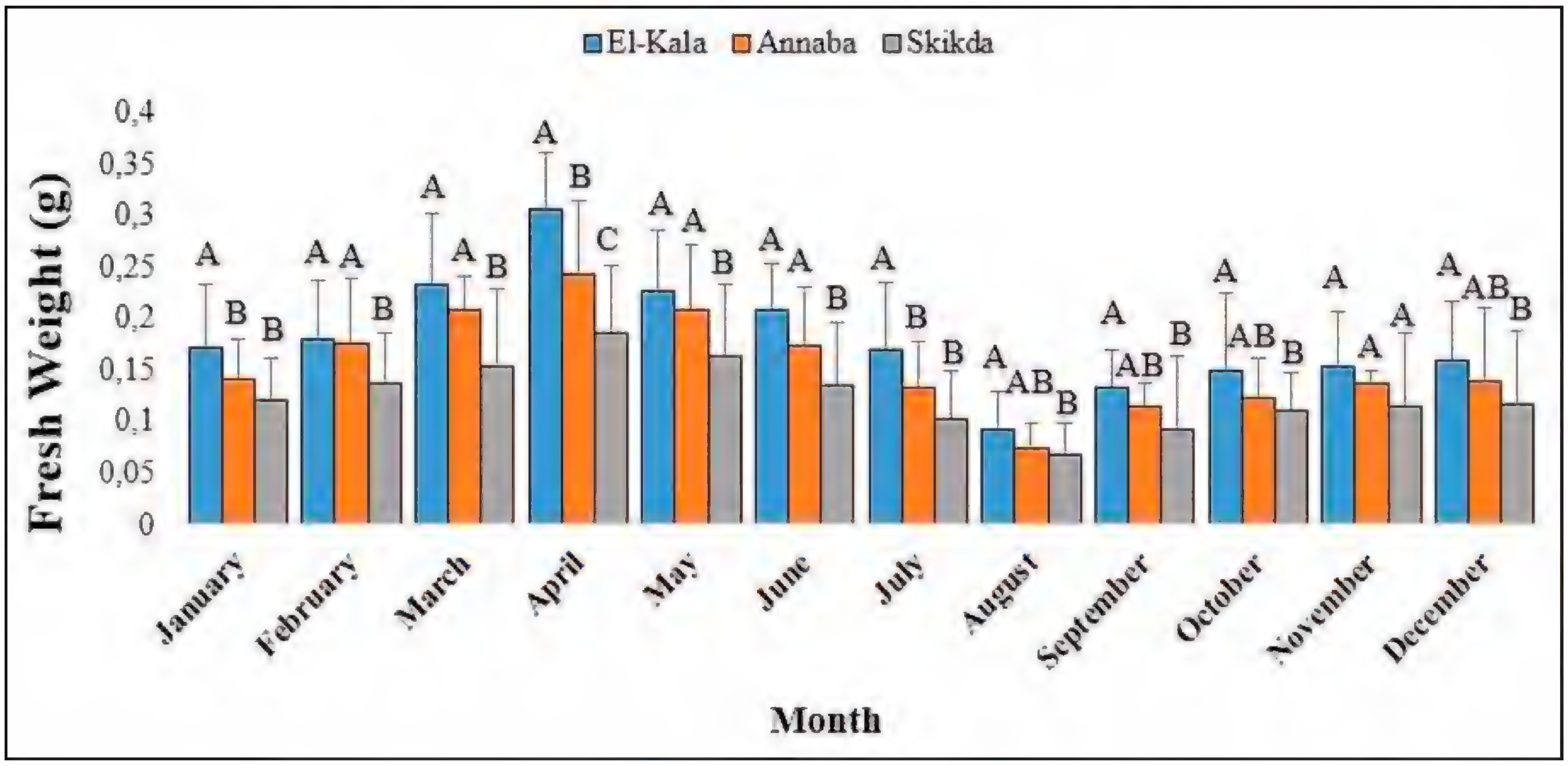


Figure 3. Monthly fresh weight variations (g) in females of *Perinereis cultrifera* at the three study sites: El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikini) during 2016 (Tukey classification).

sites into three groups for the month of April, group A represents the individuals from the El-Kala site (La Montagne), group B corresponds to the Annaba site (Saint-Cloud) which has intermediate values between the individuals from El-Kala and Skikda (Bikini), group C corresponds to the individuals from the Skikda site which have the lowest values.

In October, the test allowed us to classify the sites into the same group A where there is no difference between the three sites.

The one-way ANOVA shows that there is a non-significant difference during the months: October (P = 0.089) and December (P = 0.057) and a very significant difference during the month of August

(P=0.011), and highly significant differences were recorded in February (P = 0.008) and September (P = 0,004); However, there were very significant differences between the sites (P = <0.001) during the months of January, March, April, May, June, July and November. The two-way ANOVA (site, month) reveals a very highly significant site effect, a month effect, and a very significant site/month interaction (P<0.001).

Aspect of a coelomic puncture and annual evolution of the oocyte diameter

The average oocytes diameter evolution (Fig. 4) during the study period is represented by the figures 5, 6 and 7 corresponding to the populations sampled respectively from El-Kala (La-Montagne), Annaba (Saint-Cloud) and Skikda (Bikini). This evolution curves relating to the three studied sites show almost the same thing. We note a gradual and continuous evolution from January to May. However, during the period from February to May, two groups of females are identified, one group of females with small oocytes and the other one with larger diameter oocytes. The group of females with an average oocyte diameter of less than 50 µm begins to appear in February and then gradually disappears, as the oocytes evolve towards maturity to reach larger and larger sizes. During the period from March to May, the size of the oocytes reaches its maximum. However, the average diameter of the mature oocytes is around the order of 250 to 300 µm. In addition to all that, from June of the study year, females of large oocyte diameter disappear; this can only be explained by the death of the female spawners. The evolution curve of oocyte diameter according to time shows that the oocyte development spreads over a period of 16 months in all three populations

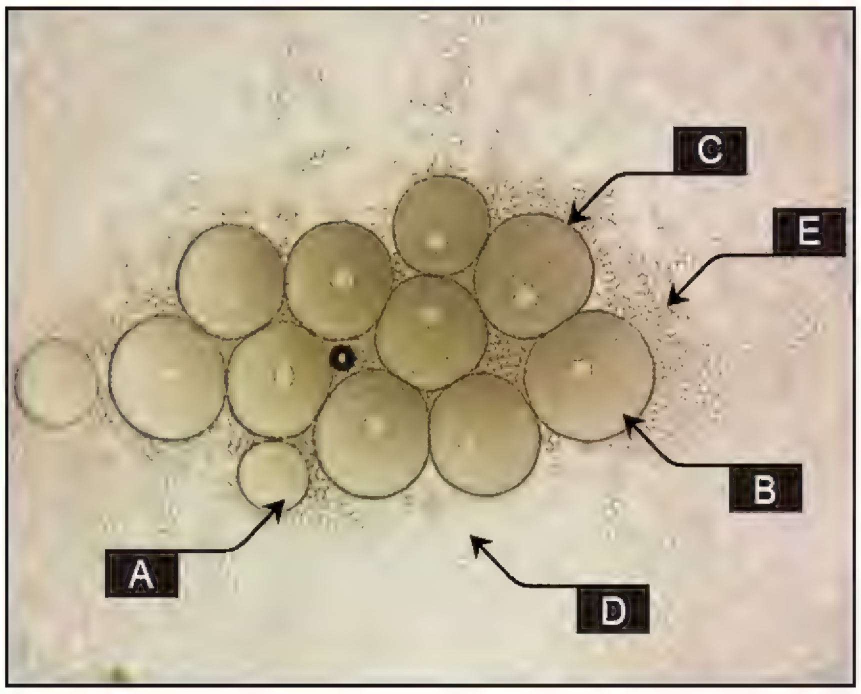


Figure 4. Aspect of a coelomic puncture of *Perinereis cultrifera* showing oocytes at different phases of development (A: immature oocyte; B: mature oocyte; C: vitellin membrane; D: cœlomic fluid; E: eléocytes).

The comparative analysis of oocyte diameter averages measurements in females sampled at the three sites shows that the last diameter is higher at the healthy site of El-Kala (Fig. 5), followed by the one of Annaba (Fig. 6) and then of Skikda (Fig. 7) during the month of April for the first population.On the other hand, the minimum diameter of oocytes for the same population is reached at Skikda in May, followed by the populations of Annaba and El-Kala during June.

Annual evolution of sexual status

The evolution of the sexual status of the *Perinereis cultrifera* population in the three sites during the annual cycle from January of the year 2016 to December of the year 2016 is shown in figures 8, 9 and 10. We note that the proportion of male individuals remains weak during the course of time, this is probably related to the fact that it is easier to differentiate early oocytes rather than spermatogonia clusters. The proportion of females varies greatly and the change in the percentage of sexed individuals over time reflects the change in the ratio of females in the total population. The proportion of sexed individuals is highest during the period from January to April.

For the populations sampled at El-Kala (La Montagne) and Annaba (Saint-Cloud), the proportion of sexed individuals is highest from February to May, and the average was around 90% at El-Kala (La Montagne) (Fig. 8), 80% at Annaba (Saint-Cloud) (Fig. 9) and 70% at Skikda (Bikini) (Fig. 10). At the beginning of May, the proportion of males and females decreased in the three sampled populations, certainly reflecting the death of mature epitokous, which corresponds to the end of the breeding season. It should be noted that a second decrease in the percentage of sexual individuals occurs in August (27.58%) in the case of the populations sampled at El-Kala (La Montagne) and

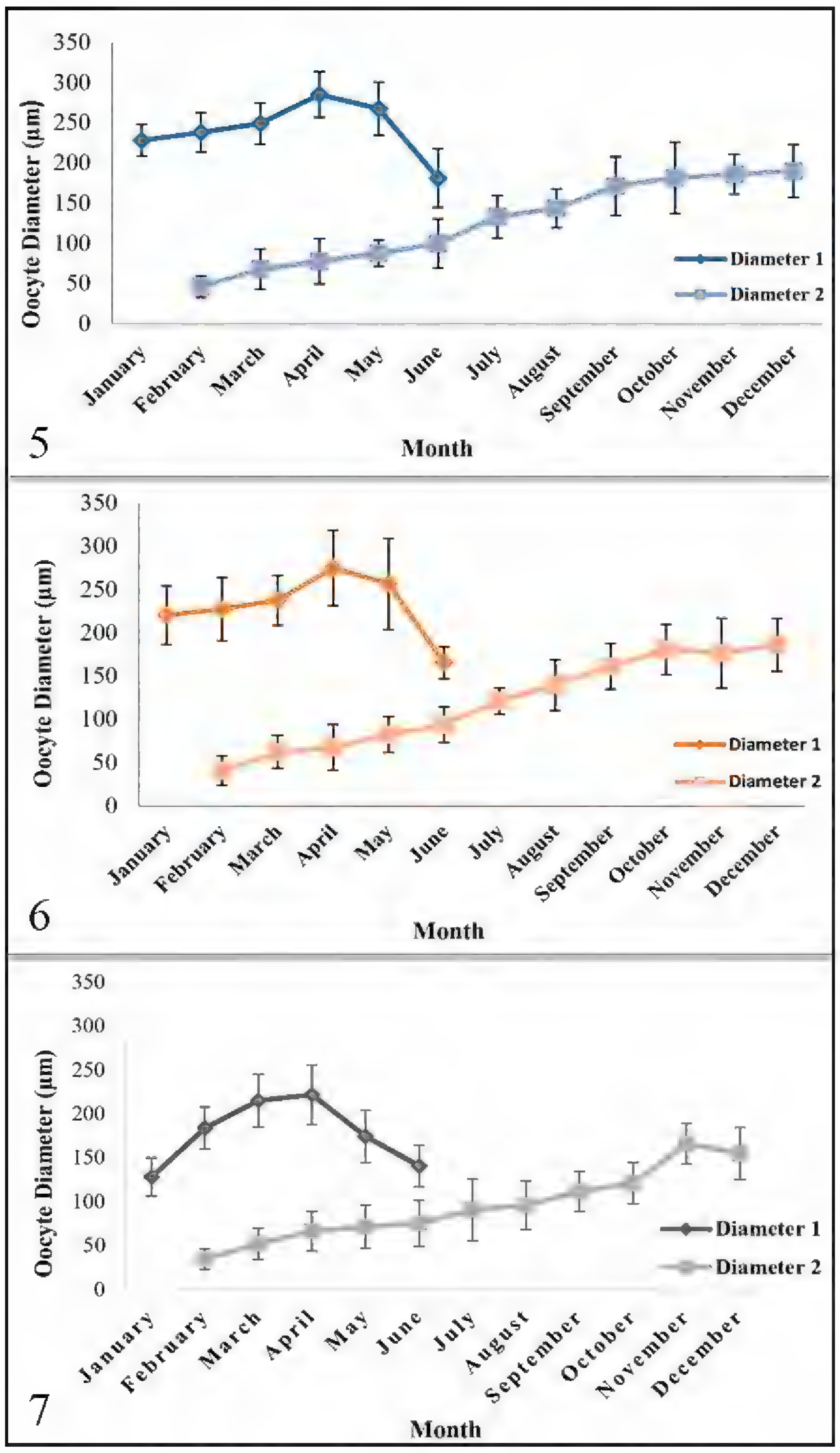
(28.56%) at Annaba (Saint-Cloud) and (41.77) at Skikda (Bikini) during the same month. This is a direct consequence of the emergence of a new undifferentiated generation of individuals in the populations sampled during this period.

Annual cycle of sexual maturity index

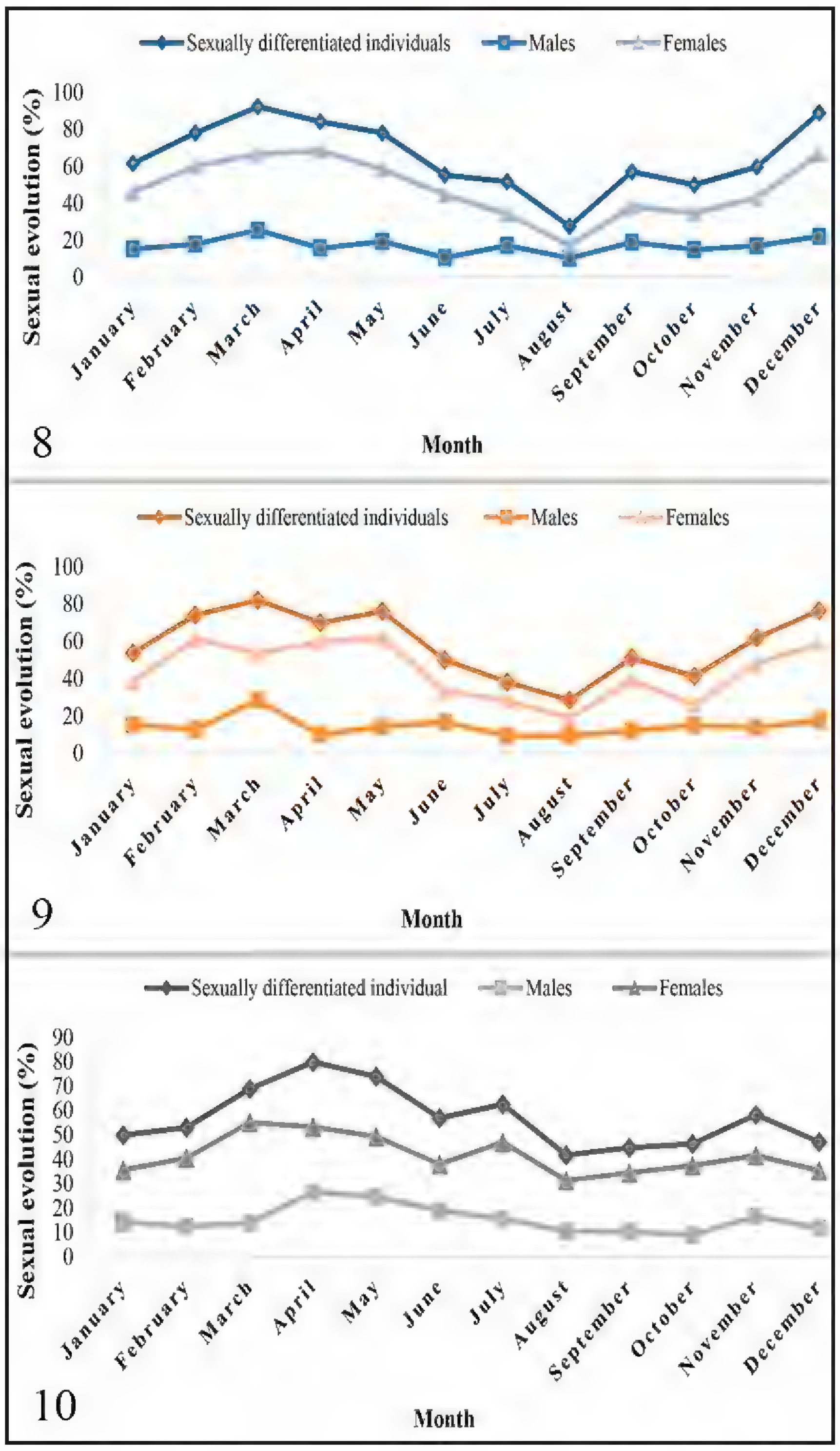
The maximum values of the sexual maturity index (SIM) were recorded in April (4.04; 2.77 and 1.70) respectively for the study sites of El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikni) (Fig. 11). However, the lowest SIM values were recorded in August (0.96; 0.79; and 0.60) respectively at the three study sites of El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikni).

Annual Size-frequency

The female coelomic puncture had a heterogeneous aspect and showed different oocyte diameters. Due to the presence of previtellogenic, vitellogenic, and sometimes mature oocytes in the coelom of females we deduced that *P. cultrifera* had an asynchronous oogenesis. For this reason, a biometric study of oocytes growth was essential to determine the reproduction period as well as the spawning season. The diameter of the oocytes present in the coelomic cavity was used as indicator of



Figures 5–7. Oocyte growth from January to December of females collected from El-Kala (Fig. 5), Annaba (Fig. 6) and Skikda (Fig. 7) during 2016.



Figures 8–10. Annual evolution of sexual status of *Perinereis cultrifera* collected from El-Kala (Fig. 8), Annaba (Fig. 9) and Skikda (Fig. 10) during the year 2016.

the maturation stages. In *P. cultrifera* these germinal elements had a wide range of dimensions, so seven groups of increasing oocytes were identified using a class interval size of 50 µm (Figs. 12–14). Oocytes that had completed vitellogenesis measured 300-350 µm. Females with small oocytes (diameter less than 50 µm) were present throughout the year (Figs. 12–14). The coelomic fluid of females collected in April contained a majority of large oocytes indicating that this period corresponded to the most intense reproductive period. From April the drastic reduction in the number of mature oocytes in the coelomic cavity was connected with spawning. A relatively high proportion of females containing mature oocytes was found in March and April in females collected at El-Kala (50%), 15–39% in females collected at Annaba and 3-19% in females collected at Skikda. During winter and summer periods we found a high proportion of females containing small and medium oocytes (Figs. 12–14).

Seasonal and intersite variation of parameters by Principal Component Analysis (PCA)

The use of Principal Component Analysis (PCA) as a preliminary and exploratory descriptive approach made it possible to visualize the structuring of the temporal and spatial variation at the three sites according to 8 variables (pH, dissolved Oxygen, Temperature, Salinity, Length, Fresh-weight, Oocyte-Diameter, SIM). The used software allowed for vectors whose direction centered on the factorial axes meaning that part of the point cloud affected by the action of the factors involved and the length indicates their intensity.

The first two factorial axes outweigh respectively 51.89% - 23.11% of the variance or about 75.01% of the total variance (Figs. 15, 16). We will retain only the first two axes for the interpretation of the analysis. The dots-area is proportional to the values taken by the variables.

The site of the city of El-Kala is influenced by a higher pH and dissolved oxygen than the other two sites (Skikda and Annaba), resulting in larger, heavier individuals with an oocyte diameter and SIM more important. The Skikda site is influenced by a higher temperature and salinity than the other two sites (El-Kala and Annaba). Annaba site is an intermediate site concerning the physicochemical parameters and the results of weight, size, oocyte diameter and SIM means.

Correlations between different studied parameters

The Spearman test allowed us to confirm that there is a positive and very highly significant correlation between the four studied parameters at El-Kala (Fig. 17), very significant at Annaba (Fig. 18) with lower values; on the other hand, at Skikda, the values are positive (Fig. 19) but much lower and not significant concerning the oocyte diameter with the maturity index and only significant for the fresh weight with the oocyte diameter.

DISCUSSION

Wetlands are ecologically very important and extremely productive ecosystems, however very sensitive essentially in transitional locations subject to environmental and anthropogenic constraints (Mouillot et al., 2005; Rossi et al., 2006; Blanchet et al., 2008). The Algerian coasts like several Mediterranean wetlands, are subject to an increasing pressure in the anthropogenic activities (urbanization, industry, pollution, aquaculture, tourism and overfishing). The consequences can be detected on the general state of ecosystems, mainly in macrofauna that is more sensitive and more exposed (Ben Mustapha et al., 1999; Ayari & Afli, 2003). Aquatic organisms in general are often con-

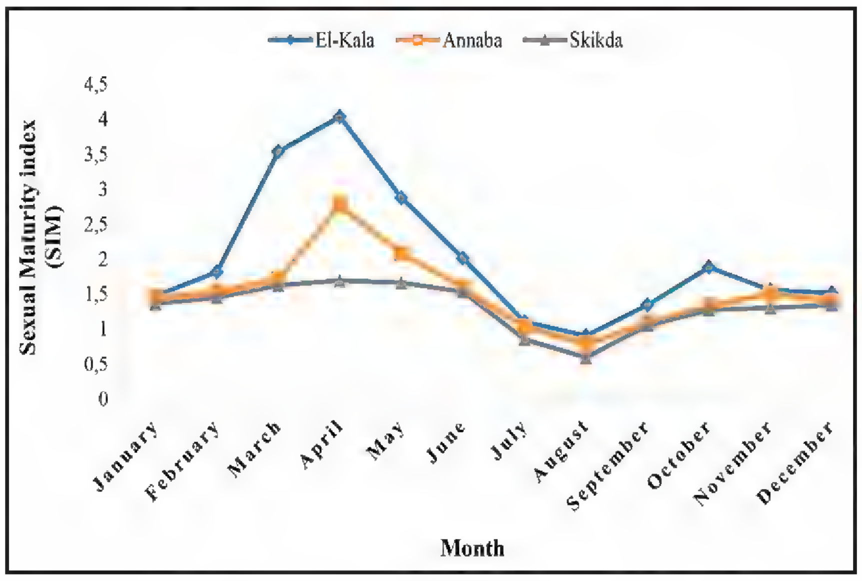


Figure 11. Monthly Sexual maturity index variations in females of *Perinereis cultrifera* at the three study sites: El-Kala (La Montagne), Annaba (Saint-Cloud) and Skikda (Bikini) during the year 2016.

fronted with fluctuations in their physical, chemical and biological environments. Changes in environmental factors imposed on these aquatic lives are usually gradual, rythmic and predictable (Ahamefula, 2014). The littoral is highly vulnerable to a wide assortment of contaminants and micropollutants directly released into the seas and oceans, to which are added those released into the air and drained by soils and rivers (Bensouda & Soltani-Mazouni, 2014).

Polychaeta are a large class in phylum Annelida. Polychaetes all live in the sea with over 10,000 species known worldwide with locations ranging from tidal zone to deep sea (Kirkegaard, 1983; Bakken & Wilson, 2005); they play an important role in the benthic niche (Kelly et al., 2006; Sampértegui et al., 2013). They have developed some features to cope with some of these adverse environmental conditions. The polychaete worms, as benthic fauna are biological parameters that indicate the overall aquatic fertility of the sediments, and the study of the polychaetes may be used as baseline information to evaluate the demersal fish stocks, as they form a major food item in the nutrition of the bottom feeders. In addition, and more importantly, they could be used as good biological indicators of marine pollution. The polychaetes are one of these sentinel organisms.

Seawater temperature, salinity, dissolved oxygen and pH are important components of seawater quality.Temperature is an important ecological factor; it controls the intensity of reproduction (the quantity of gametes produced) (Mackie & Scloesse, 1996) and stimulates the process of gametogenesis in correlation with other factors which leads to variations in pollutant accumulation rates (Tran et al., 2001, 2002).

One of the major and direct impacts of global warming is the rise in the surface water temperature. According to IPCC (I.P. on Climate change, 2007), global sea surface temperature is approximately 1°C higher now than 140 years ago, and is one of the primary physical impacts of climate change. Projections made in 2007 by the International Panel for Climate Change (IPCC) show that sea surface temperatures will continue to increase globally throughout the 21st century. This rise leads to increase in the kinetic energy of the water and consequently decreases the oxygen-holding capacity of surface waters, which can decrease productivity in surface waters already stressed by biological oxygen demand (BOD) (Jacoby, 1990) and this translates to decrease in dissolved oxygen.

Temperature is one of the most sensitive physicochemical parameters to natural changes, it varies according to the outside temperature (air), seasons, the geological nature of the soil and the depth of the water level relative to the sediment surface (Rodier et al., 2005), and anthropogenic changes such as wastewater discharges. In the three study sites, water thermal values did not show large variations. In addition, the temperature variation has effects on all other measured parameters such as pH, water conductivity, and salinity level as it has an effect on

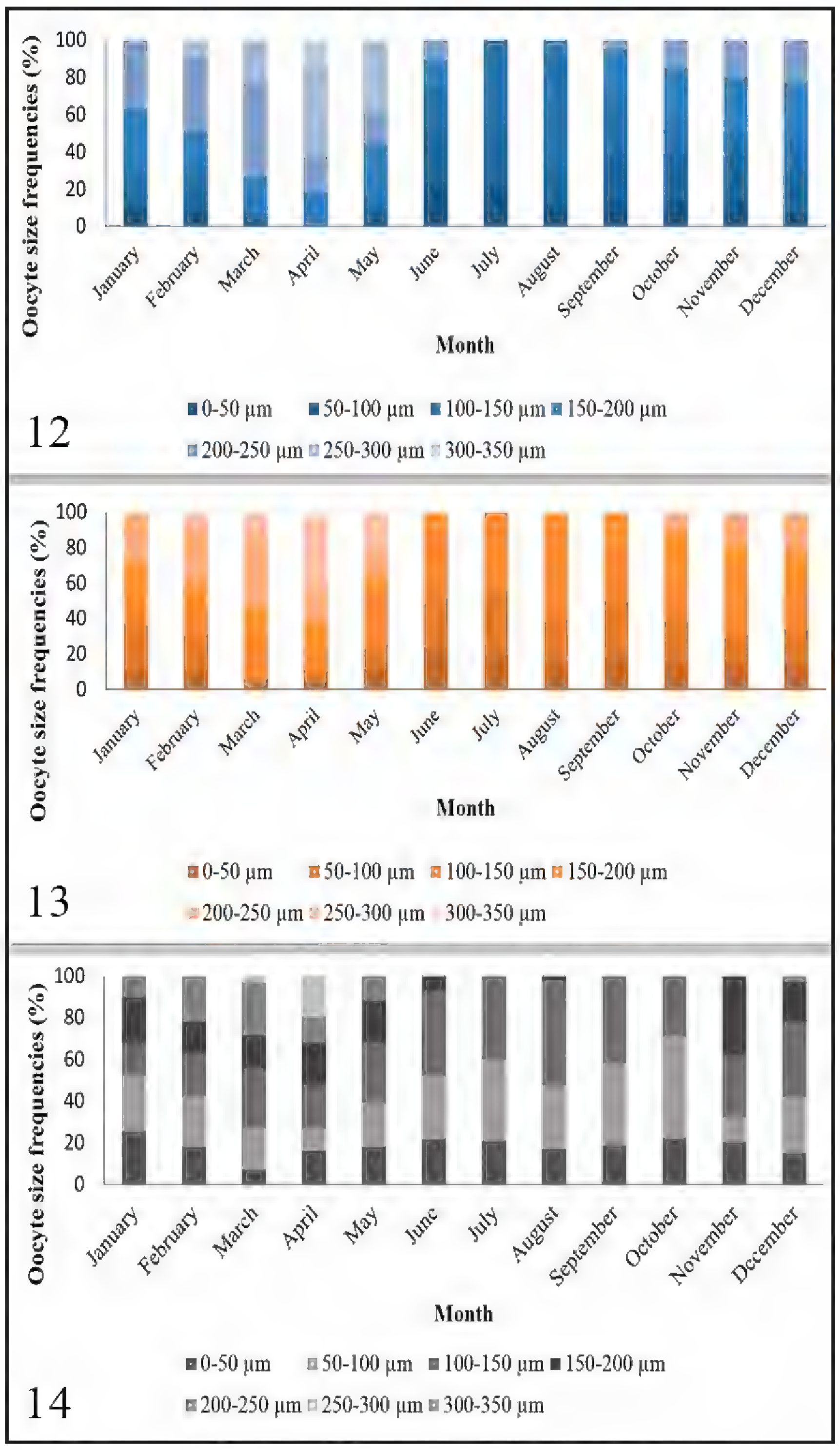
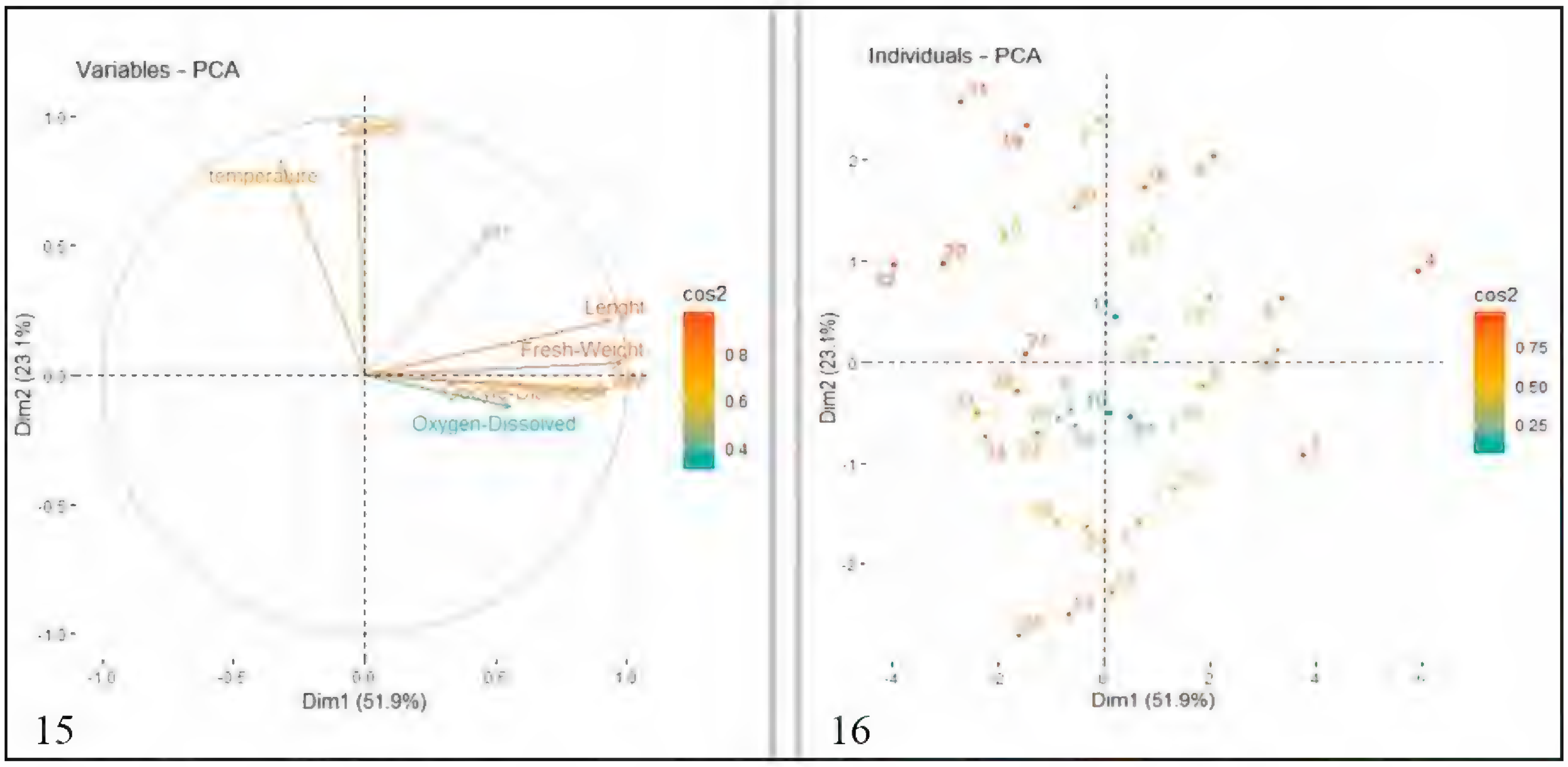


Figure 12–14. Size-frequency distribution of oocytes in females of *Perinereis cultrifera* at El-Kala (Fig. 12), Annaba (Fig. 13) and Skikda (Fig. 14) study sites from January to December (Fig.10) during the year 2016.

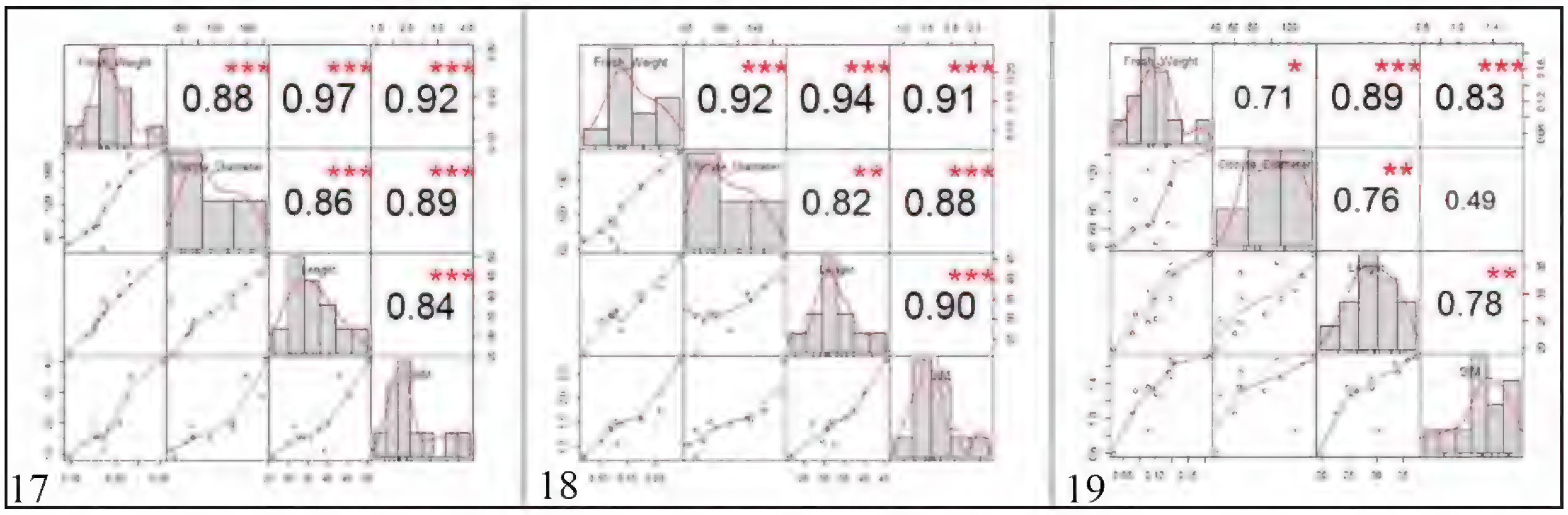
all degradation reactions, mineralization of organic matter and development. The increase in temperature favors, with other factors, primary productivity and therefore an increase in food for aquatic fauna (Bremond & Vuichard, 1973).

In the three study sites, water thermal values did not show large variations. However, they revealed the existence of a typically Mediterranean seasonal cycle. The recorded pH values demonstrated a slight water alkalinity and did not show a variation between the three sites. Salinity largely determines the biological processes, but also the chemical processes in the water. It is also known by its influence on the bioavailability of metals (Durou et al., 2005). It determines the distribution and dynamics of species (Verschuren et al., 2000; Llanso et al., 2002; Teske & Wooldridge, 2003; Pasquaud, 2006). Salinity showed the absence of a difference between the seasons with a nonsignificant decrease in spring due to the arrival of continental freshwater, which is linked to the abundance of rains that dilute seawater. Our results seem to be in agreement with the means observed in the Mediterranean Sea which are in the order of 38-39 PSU (Aminot & Kéroual, 2004b) and with those measured on the Algerian coasts, particularly on the Annaba Gulf (Hadjadji et al., 2014; Ounissi et al., 2014; Kadri et al., 2015; Amri et al., 2017b). Oxygen is only sparingly soluble in water and therefore is less abundant in water than in air. The solubility of oxygen, and hence its availability as dissolved oxygen in water, decreases with rising temperature and increasing salinity and depth of the water body. Therefore organic pollutants and aerobic organisms quickly deplete oxygen in both water and sediment of the water body (Chukwu, 2011). Very low oxygen concentrations occur at the muddy bottom which serves as the habitat of the benthic organisms. Compensatory mechanisms have been evolved by these organisms to anticipate and deal with this condition. In order to survive, organisms adjust, regulate, tolerate and resist these changes (Odiete, 1999). The marine Annelida, the polychaetes, have also developed some features to cope with some of these adverse environmental conditions. Ahamefula Nkwoji (2014) has shown that adaptation to hypoxia was highest in Nereis diversicolor, followed by *Platynereis dumerilii* and least in *Perinereis cultrifera.* This could be adaptation to their different ecological niche. *Perinereis cultrifera* live son the surface of well ventilated sandy sediment, sheltered by the rocks. Dissolved oxygen is consumed during the heterotrophic oxidation of organic matter, and respiration by wildlife, and aquatic flora. The amount of dissolved oxygen in water is necessary for aquatic life and the oxidation of organic matter essential for aquatic life as food (Tran et al., 2001, 2002). The dissolved oxygen of the sea water at site 3 revealed significantly lower mean values compared to the other sites, particularly at summer, this would probably be related to biodegradable organic matter loads and to industrial discharges from the petrochemical platform. These will undergo oxidation whitch will result in increased consumption of oxygen leading to a decrease in its content in water. The results obtained of temperature, pH and the dissolved oxygen correspond with the work performed in the northeastern coast of Algeria (Kadri et al., 2015; Amri et al., 2017). Change in timing of spawning and life cycle of Polychaetes in different geographical regions could be a consequence of different local temperature regimes (Kristensen, 1984), In the case of the Atlantic Coast of El Jadida (Morocco) differences in recruitment can be attributed to climatic factors (Aït Alla et al., 2006).

The study of morphometric parameters, total length, body weight and oocyte diameter was undertaken for the species *P. cultrifera* in order to detect a possible effect of pollution on the growth and reproduction of this species. The responses of organisms to chemical contamination of the environment allow them, to a certain extent, to maintain or restore a certain balance. These homeostatic mechanisms are reflected at the individual level by energy expenditure (Le Gal et al., 1997). A change in growth may reflect a change in the amount of energy present in an organism and suggests a decrease in energetic conversion to somatic tissues. Organisms can increase their survival in an environment polluted by development of resistance with an evolutionary response to pollutants. However, the evolution of this resistance is usually accompanied by an expensive physical form, such as reduction of reproduction, growth (Wirgin & Waldman, 2004) or reduced tolerance to various stressors (Meyer & De Giulio, 2003). The monthly follow-up of the biometric measurements shows a similar evolution in the females of the three populations coming from the three sites. The weight increases gradually at the beginning of the study period, reaching a maximum



Figures 15, 16. Principal component analysis (PCA) based on the spatiotemporal variation. Factorial plane: D1: 51.90%, D2: 23.11%. (Fig. 15): correlation circle of variables assayed with the first two principle axes. (Fig. 16): projection of all studied parameters on the first two principal axes.



Figures 17–19. Tests of correlation between four parameters (fresh weight, length, oocyte diameter and maturity index) at El-Kala (Fig. 17), Annaba (Fig. 18) and Skikda (Fig. 19) study sites.

value during the two months April and May in the three study sites. This increase is followed by a decrease in weight at the beginning of June. This corresponds with the sexual differentiation period. A number of authors have observed that different species of bivalves exposed to environmental pollution may have slow growth (Peteiro et al., 2006). It can also be associated with episodes of chemical stress that involve a loss of weight of the tissues of organisms, linked to a mobilization of energy reserves for their detoxification (Modassir & Ansari, 2000). Although the three populations show a similar evolution, it is found that the values recorded in the El-Kala (El-Morjène) females are always high compared to those of the females of the two other sites. This is in agreement with several studies carried out on *Nereis diversicolor* showing that these biometric parameters in worms coming from the contaminated site never reached a higher value than those of the healthy site. They also confirmed that worms living in disturbed environments have a reduced weight gain stage (Durou et al., 2007; Durou et al., 2008; Gillet et al., 2008; Mouneyrac et al., 2009). Like weight, the length of individuals increases gradually at the beginning of the study period, reaching a maximum value during the months of April and May in all sites followed by a decrease in early June. These results align with those of monthly weight changes. Although, the three populations show a similar evolution, it is found that the values recorded in the females of El Kala (El-Mordjène) are still high than those recorded in the females of the two sites Annaba (Saint Cloud) and Skikda (Stora). The individuals collected at Skikda coast (contaminated site) are smaller than those at El-Kala coast (healthy site) and the difference between the two populations is very highly significant. Dutrieux et al., (1989) indicate that chronic exposure to organic pollutants of a Neridiae species, *Nereis*, results in a decrease in average size as a function of the pollution gradient.

A study on the effect of *Nereis diversicolor* resistance to metals showed a significant decrease in growth factors compared to the non-resistant population (Pook et al., 2009) than in *P. cultrifera* and other species of Nereidae, the biometric characteristics strongly differ depending on the geographical location (Rouabah & Scaps, 2003; Çinar & Ergen, 2005, Çinar & Altun, 2007, Rouhi et al., 2008).

Comparing with data from the literature, the biometric parameters varied according to the geographical populations. However, in the Atlantic French coast (Cazaux, 1965) the adult individuals have a weight of 3 g. In the same way, in the north Sea (Scaps et al., 1992), it varies from 3 to 6.6 g, whereas in Tunisia (Zghal & Ben Amor, 1989), the specimens have an average weight of 0.24 g, and for the populations of El Jadida in Morocco the weight of adult individuals varies between 0.11 and 0.65 g (Rouhi et al., 2008). According to Durchon (1957), this polymorphism could have two origins: either internal and related to the genetics or the hormones, or external and depending on the abiotic factors (temperature, salinity, food, etc.). Several authors clarified the variability of the dimensional structure according to the bathymetric level. Scaps et al. (1992) revealed that the large sexually differentiated individuals are dominant in the bottom of the zone with the algae *Fucus serratus*; whereas at the top it is the individuals of small size which dominate. The same observation was made by Miron & Desrosiers (1990) for *Nereis virens*.

Sexually differentiated individuals for the three populations from the three study sites were observed each month of sampling. Their percentage was the highest during the study period until May, indicating that the majority of them was sexually mature, and about to reproduce; however, the sexually undifferentiated individuals were very marked from June to July when there is also a clear decrease in the population of mature age during these two months, and this is necessarily the result of the death of the parents.

Our results are in agreement with the work on *P. cultrifera* present in Algeria (Rouabah & Scaps, 2003, Rouabah et al., 2008). According to these authors, the increase in the proportion of individuals of both sexes corresponds to the period OF the most intense reproduction, as well as the sexual differentiation of second-generation individuals. If accompanied by an increase in the proportion of immature individuals, it reflects the emergence of a new generation of undifferentiated individuals.

The sex ratio determined for the two populations of *P. cultrifera* reveals that females are more numerous than males. This result goes in the same direction as Nereidae (Mouneyrac et al., 2012; Mettam et al., 1982; Durou et al., 2008; Mouneyrac et al., 2009), probably due to the fact that it is very difficult to identify spermatic plaques (Rouabah & Scaps, 2003; Rouabah et al., 2008); However, our result contradicts that of Prevedelli & Simonini (2003), who reported that the sex ratio in a population of *P. cultrifera* taken from a bracket (Venice lagoon) is in balance.

The biometric study of oocyte growth of three populations of *P. cultrifera* showed that oocyte growth is asynchronous, and the reproduction is more intense from March to May; however the oocytes take 9 to 12 months to mature and their diameter at maturity is approximately 200 µm; contrary to what is commonly admitted, we found different diameters in the same oocytes; moreover, in related species such as *Platynereis dumerilii* (Fischer & Dorresteijn, 2004) and *Nereis virens* (Hoeger et al., 1999), oocyte growth is synchronous. Our results confirm previous observations on the mode of reproduction of *P. cultrifera* in the east coast of Algeria (Daas et al., 2011), who found that individuals assigned to *P. cultrifera* reproduce exclusively by epitoky. These results are in disagreement with those reported from the bay of Algiers (Rouabah et al., 2008) indicating that reproduction is of an atokous type. The mode of reproduction of *P.cultrifera* has been examined at other sites in the Mediterranean Sea by other authors. Reproduction is reported to be of an epitokous type at Salammbô near Tunis (Zghal & Ben Amor, 1989) and in the Venice lagoon (Ansaloni et al., 1986), whereas it of an atokous type in the area of Marseille (Perès & Rancurel, 1948). Mature individuals were found in May at Salammbô (Zghal & Ben Amor, 1989) and in March in the Venice lagoon (Ansaloni et al., 1986).

Our results are in agreement with Rouabah & Scaps (2003) who determined the ovogenetic cycle of *P. cultrifera* sampled from Saint-Cloud (Annaba). They confirmed that the oocyte growth spreads over a period of 16 months, and that the breeding takes place in late April early May. The same study has highlighted two groups of females that are present during ovogenesis, one carrying a large oocyte diameter, and the other a small diameter. This last observation was confirmed by Rouabah et al. (2008) on two populations, from Pointe Pescade and Figuier (Bay of Algiers). They also demonstrated that the maturity of oocytes takes place after 9 to 12 months from the recruitment of ovogonies.

Perinereis cultrifera is a semelparous species, the reproduction leads to the death of the individuals after liberation of the gametes, however one notes that in the month of June there is still a group of females bearing a large diameter, which decreases during July, which does not suggest that it is a new cohort of females in process of ovogenesis. This remark was observed by Golding & Yuwono (1994) in *N. diversicolo*r which suggests that there are individuals who fail to reproduce, in which the oviposition has been blocked. This has been explained by the presence of a second oviposition, and is in agreement with Rouabah et al. (2008) who demonstrated that reproduction in *P. cultrifera* from the bay of Algiers takes place throughout the year, but it is more intense from the month of March to May.

In *Nereis virens*, oogenesis takes place in almost a year and a half, in three phases: a first phase of slow growth, an intermediate phase during which the oocytes increase in size by about six times, and a last phase during which the oocytes will reach their final stage of development (Hoeger et al., 1999); likewise according to Zribi et al. (2007), oogenesis occurs in the same way in most Nereidae; in *P. macropus*, three categories of oocytes have been classified according to their size, that of pregenesis, that of vitello genesis, during which the oocytes have a markedly large size; and that at the final stage of maturity where the oocytes reach their maximum diameter.

It should be noted that the oocyte diameter recorded in the females of the two sites Annaba (Saint-Cloud) and Skikda (bikini) was significantly lower than that recorded in the females of El-Kala, this translates into the storage of reserves during the process of oogenesis that seems inferior in this population. However, while in June and July, the result is likely due to the appearance of females of the new generation undergoing oogenesis. Our results are not in agreement with those of El-Barhoumi et al. (2013) and Prevedelli et al. (2007) who showed that the gonadal activity was maximal during summer period in both sexes of another Polychaete *Marphysa sanguinea* in the Lagoon of Tunis.

In addition, observations on the benthic phase of the life cycle of *P. cultrifera* have been carried out in the English Channel and the Atlantic coast of France. Reproduction in the English Channel (Herpin, 1925) and the Arcachon basin (Cazaux, 1965) is of an epitokous type and individuals assigned to *P. cultrifera* have 3-year life span. In the Arcachon basin, the reproductive season is short and spawning occurs from late April to early June (Cazaux, 1965). *P. cultrifera* is widely distributed along the Mediterranean coast and frequently used in marine pollution studies (Scaps et al., 2000; Guemouda et al., 2014). In the English Channel specific observations made by (Herpin, 1925) indicated that reproduction takes place from May to June and sometimes July. However, we also found a relatively high proportion of females containing mature oocytes from March to April; so, we can consider that the reproductive period extends from January to April. Therefore, the spawning period may change in different years or sites because gametogenesis and gamete release could be influenced by temperature, as in a number of polychaetes (Olive et al., 1997; Gibbs, 1968; Giangrande & Petraroli, 1991; Predevelli, 1994; Olive, 1995).

Seasonal variations of SMI in females in both sites, usually range from 1.5 and 4 corresponding to the presence of worms in several sexual maturity stage (indifferent, proliferation, vitellogenesis and mature). According to Durou & Mouneyrac (2007), several consistent differences in SMI, energy reserves and hormone levels in *Nereis diversicolor* were observed between worms according to their origin; the multi-polluted Seine and the comparatively clean Authie estuaries; SMI was usually ranged from 2 and 3 in this species. The presence of estrogen receptor in eleocytes supports a potential role for 17β-estradiol in vitellogenesis (Garcia-Alonso & Rebscher, 2005). Then, it must be hypothesized that steroid hormones in *N. diversicolor* have to be synthesized at the beginning of oocyte development; at later stages of this process steroid hormone levels may decrease due to a shift in the steroidogenesis, perhaps similar to that shown in lower vertebrates (Nagahama, 1987).

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Noteworthy records of the Geoffroy's tailless bat and the Eastern Pipistrelle in Copán, western Honduras (Mammalia Chiroptera)

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ABSTRACT Of the 113 bat species that occur in Honduras, the Geoffroy's tailless bat, *Anoura geoffroyi* Gray, 1838, and the Eastern Pipistrelle, *Perimyotis subflavus* (F. Cuvier, 1832), are among the least studied. Here we report the first records of *A. geoffroyi* and *P. subflavus* in a cave known as El Ermitaño in Cerro Azul Copán National Park (abbreviation in Spanish PANACAC) in the department of Copán, western Honduras, based on a survey from 30 October to 03 November 2017. We accumulated 840 m^2.h of sampling effort and captured 13 individuals including four of *A. geoffroyi* and two of *P. subflavus*. These records represent the first ones of *P. subflavus* in PANACAC and Copán, the westernmost records and the highest altitudinal record of the species in the country, and is the first time that *P. subflavus* has been found roosting together with *A. geoffroyi*. PANACAC might represent an important site for conservation for both species in Honduras, however, the protected area has been affected by the extension of crops and cattle. We recommend forest management and environmental education of bats to the people of Florida as a solution to keep stable bat populations.

KEY WORDS *Anoura geoffroyi;* bats; conservation; new records; *Perimyotis subflavus.*

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INTRODUCTION

Goodwin (1942) mentioned that the mammalian fauna of Honduras, more or less, escaped the attention of early collectors, and there have been only scattered accounts of the mammals of Honduras. However, this is a situation that has not changed after 78 years. Chiroptera is an order in Honduras among other groups of mammals that have few studies because most of the recent distributions and ecology comments are based on historical records (Turcios-Casco & Medina-Fitoria, 2019). Currently, 113 bat species occur in Honduras (Turcios-Casco et al., 2020), and the Geoffroy's tailless bat, *Anoura geoffroyi* Gray, 1838, and the Eastern Pipistrelle, *Perimyotis subflavus* (F. Cuvier, 1832), are among the least studied.

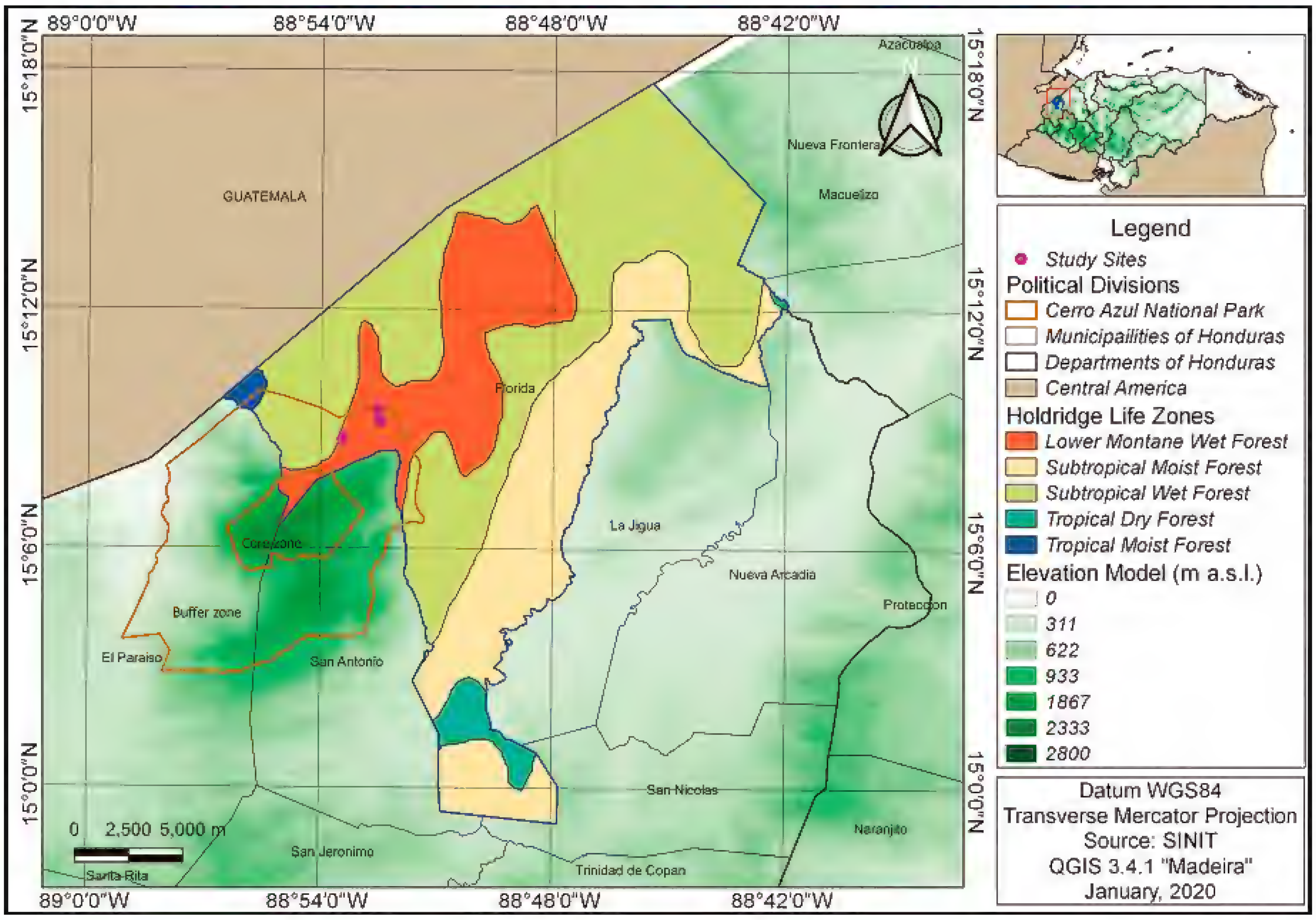
Here we report the first records of *P. subflavus* and *A. geoffroyi* in the municipality of Florida as part of the Cerro Azul Copán National Park (abbreviation in Spanish is PANACAC) in the department of Copán in western Honduras. Conservational and ecological comments are also given for both species based on the information collected in the field.

METHODS

The sampling site was in the protected area known as the Cerro Azul Copán National Park (PANACAC) in Florida (15°02'45"N, 88°51'59"W–15°10'04"N, 88°51'59"W; 1203–1550 meters asl) municipality of Copán in western Honduras (Fig. 1). Based on Holdridge's (1967) life zones, we sampled in a lower montane wet forest. The land coverage of the municipality is mainly crops/pastures (48.24%), secondary wet vegetation (12.69%), and coffee plantations (11.86%) (ICF, 2015). The average temperature is between 24.9–25.6°C, and the annual precipitation is between 1312.4–1501.9 mm (UNAH & IHCT, 2012). The buffer zone of PANACAC has an extension of 10,512.587 ha and the core zone a total of 1,570.515 ha, and despite of its high extension, it is one of the least studied protected areas in Honduras (Fig. 2).

We captured bats with two 12 x 2.5 m mist nets with denier mesh of 35 mm and were set at ground level and opened from 17:20 to 01:30. Their position at each site was selected based on the surrounding vegetation and topography, water bodies, and fruiting and flowering plants (Kunz & Kurta, 1988). Sampling effort was calculated with the area of the two mist nets times the number of hours the mist nets remained opened for the ten days (Straube & Bianconi, 2002). All the individuals were manipulated according to the guidelines of the use of mammals in wildlife research (Sikes et al., 2019), and were identified based on Timm et al. (1999); Medellín et al. (2008), Reid (2009), and Mora (2016).

A 100 g spring scale was used to obtain body mass, and the following external measurements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15°6'0"N
15°0'0"N
GUATEMALA
Azacualpa
Nueva Frontera
Macuelizo
Florida
Core zone
Buffer zone
El Paraiso
San Antonio
La Jigua
Nueva Arcadia
Proteccion
San Nicolas
Naranjito
San Jeronimo
Trinidad de Copan
Santa Rita
0 2,500 5,000 m
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● Study Sites
Political Divisions
Cerro Azul National Park
Municipailities of Honduras
Departments of Honduras
Central America
Holdridge Life Zones
Lower Montane Wet Forest
Subtropical Moist Forest
Subtropical Wet Forest
Tropical Dry Forest
Tropical Moist Forest
Elevation Model (m a.s.l.)
0
311
622
933
1867
2333
2800
Datum WGS84
Transverse Mercator Projection
Source: SINIT
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Figure 1. Studied sites at Cerro Azul National Park in western Honduras in Copán. Note that all the localities are in a lower montane wet forest and are part of the buffer zone of the protected area.

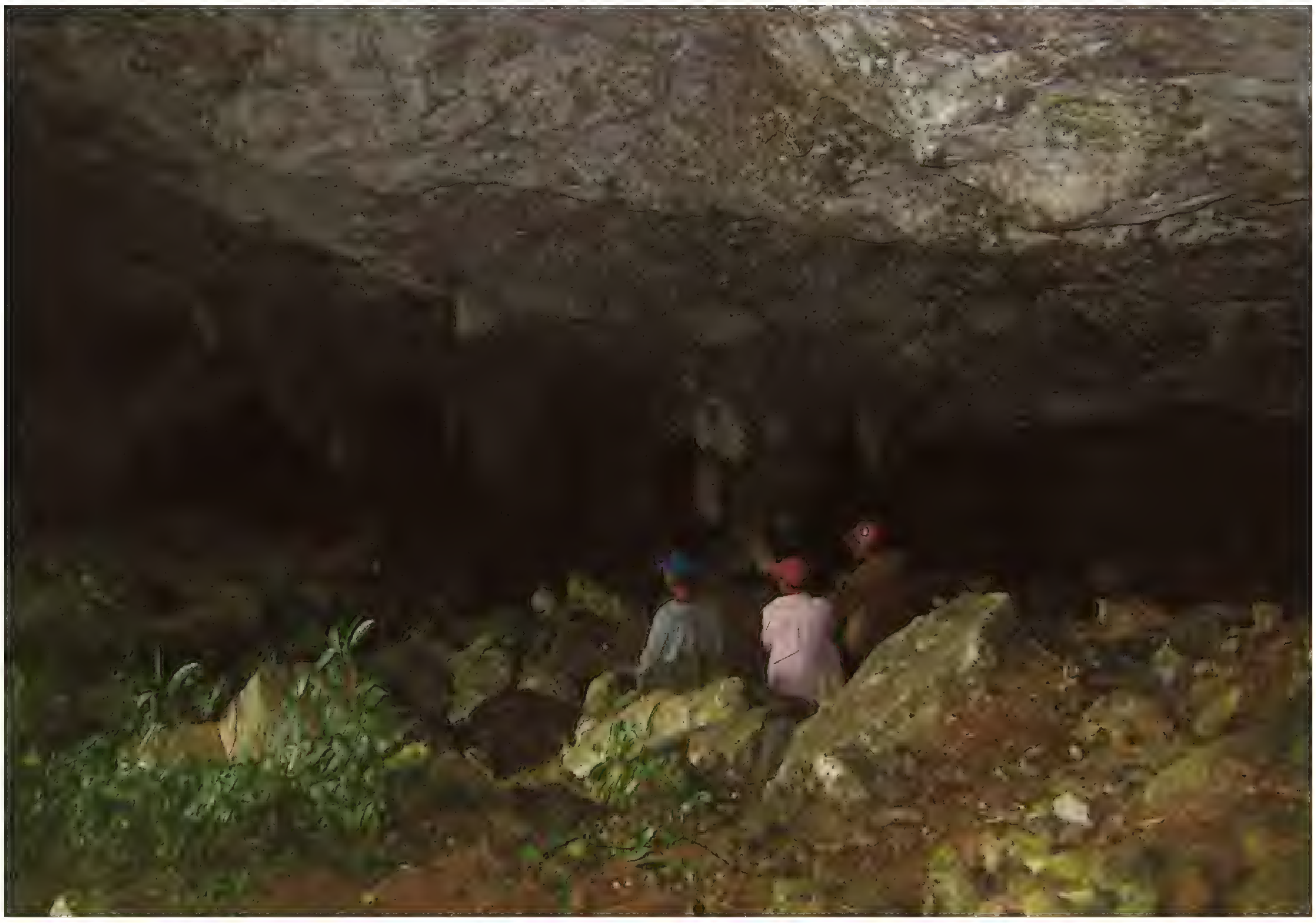


Figure 2. The entrance of the cave of El Ermitaño in PANACAC in which *A. geoffroyi* and *P. subflavus* were roosting.

were recorded to the nearest 0.01 mm with a digital caliper, following Srinivasulu et al. (2010), except for the tragus length and width, in which case Dietz & von Helversen (2004) were followed: forearm length (FA); tibia length (Tib); ear length (E); ear width (EW); thumb length (Th); noseleaf length (LN); tragus length (Tr); tragus width (TrW); calcaneus length (Ca); tail length (T); body length (BH); hindfoot length (HF); wingspan (WS); third metacarpal length (3mt); length of the first phalanx of digit III (1ph); length of the second phalanx of digit III (2ph); and length of the third phalanx of digit III (3ph).

RESULTS

From 30 October to 3 November 2017 we accumulated 840 m^2.h and captured 13 individuals (0.015 individuals per m^2.h) of seven species (0.008 species per m^2.h) from Phyllostomidae (76.9% of the captures), Mormoopidae (7.7%), and Vespertilionidae (15.4%). The following species (relative abundance in parentheses) were recorded: *Anoura geoffroyi* (0.31), *Desmodus rotundus* (E. Geoffroy, 1810) (0.15), *Diphylla ecaudata* Spix, 1823 (0.15), *Perimyotis subflavus* (0.15), *Artibeus jamaicensis* Leach, 1821 (0.08), *Dermanura azteca* K. Andersen, 1906 (0.08), and *Pteronotus mesoamericanus* Smith, 1972 (0.08).

Anoura geoffroyi Gray, 1838

MATERIAL EXAMINED. Honduras, Copán, El Ermitaño (15°08'44"N, 88°52'30"W; 1520 m asl). Manfredo Alejandro Turcios-Casco, Claudio Josué Mejía-Suazo, Danny Josué Ordoñez Bautista; 31 October 2017 (4 adult males, Figs. 3, 4).

All the non-reproductive males were captured between 18:00-20:25 (16ºC and 100% relative humidity, for both captures), while the moon phase was first quarter with illumination between 76 and 81% of moonlight. Ectoparasites were found in three individuals. One individual vocalized distress calls while it was being taken out from the mist net and attracted other bats that tried to help it escape by distracting or frightening the predator (Eckenweber & Knörnschild, 2016; Ávila-Palma et al., 2019).

Identification. All the individuals were identified as *A. geoffroyi* because is the only Glossophaginae in Honduras with reduced and heavily furred uropatagium (Mora, 2016).

External measurements (in mm) are as follows: FA = 40.92–41.23, Tib = 13.41–15.02; E = 9.74–12.83; EW = 5.75–7.70; Th = 4.85–5.07; LN = 4.63–5.17; Tr = 3.44–4.98; TrW = 2.71–2.84; Ca = 2.14–3.40; BH = 37.88–45.10; HF = 8.63–11.22; WS = 321.87–336.24; 3 mt = 38.29–42.77; 1ph = 13.22–14.70; 2ph = 21.50–23.04; 3ph = 13.30–15.12; body mass = 14.0–18.0 g.

Distribution and Biology. *Anoura geoffroyi* is distributed from Sinaloa and Tamaulipas, México, through Central America (excluding Yucatán Peninsula) to Perú, Bolivia, and southeast Brazil to northwestern Argentina (Baumgarten & Viera, 1994; Reid, 2009), from elevations from 400 to 3600 m asl (Solari, 2016). Even though *A. geoffroyi* is generally tolerant of human disturbance (Handley, 1976), it is considered a bat with a wide distribution (Ortega & Alarcón, 2008).

Anoura geoffroyi is considered insectivorous and facultative nectarivorous (Gardner, 1977). It roosts in a variety of refuges including caves and tunnels (Reid, 2009) and may be captured near streams, croplands, evergreen pine forests, deciduous *Quercus* forests, and cloud forests (Handley, 1976; Ceballos González & Galindo Leal, 1984; Ortega & Alarcón, 2008).

Status and conservation. Currently, this species is considered as LC (Least Concern) by the International Union for the Conservation of Nature (IUCN) (Solari, 2016).

Perimyotis subflavus (F. Cuvier, 1832)

Material examined. Honduras, Copán, El Ermitaño (15°08'44"N, 88°52'30"W; 1520 m asl). Manfredo Alejandro Turcios-Casco, Claudio Josué Mejía-Suazo, Danny Josué Ordoñez Bautista; 31 October 2017 (2 adult males, Figs. 5, 6).

Individuals were captured between 17:15–17:17 (16ºC and 100% relative humidity for both captures), while the moon phase was first quarter with illumination between 76 and 81% of moonlight. Both individuals were in a non-reproductive state, ectoparasites were found in both of them, and one individual vocalized distress calls as described before.

Identification. Both individuals were identified as *P. subflavus* because we observed two premolars on each of them, the tragus was curved with a rounded tip, and the tail membrane sparsely covered with yellowish hair from base to below level of knee (Timm et al., 1999; Reid, 2009).

External measurements (in mm) are as follows: FA = 34.56–35.00; Tib = 14.3–14.8; E = 7.00–9.65; EW = 3.55–4.99; Th = 3.42–3.37; Tr = 5.11–5.97; TrW = 1.55–2.84; Ca = 8.46–9.34; T = 28.4–29.71; HF = 6.41 (second individual escaped after taking this measurement); WS = 231.113–24.121; 3mt = 31.23–31.61; 1ph = 9.76–9.62; 2ph = 8.44–9.71; 3ph = 6.62–7.61; body mass = 4.0–5.0 g.

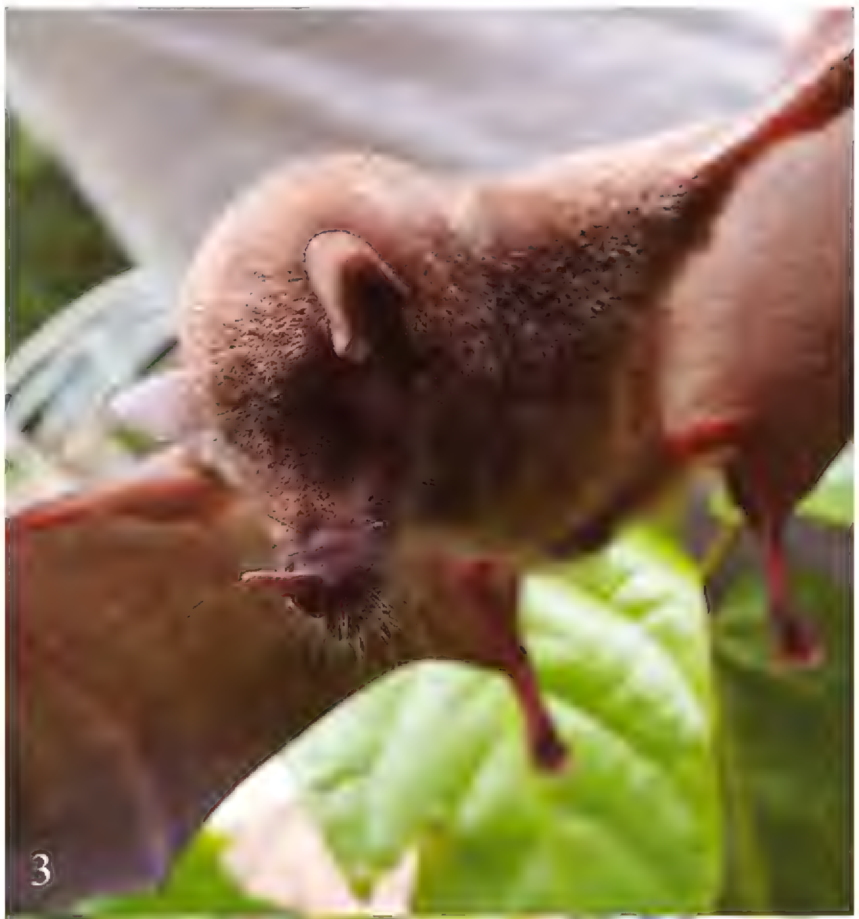
Distribution and Biology. *Perimyotis subflavus* is a vespertilionid bat known to occur from southeast Canada and eastern United States (Fujita & Kunz, 1984) to Guatemala, Honduras (McCarthy et al., 1993) and Nicaragua (Medina-Fitoria et al., 2015) from lowlands (Reid, 2009) to 2097 m asl (Solari, 2018). Even though is considered locally common in the United States and Canada (Reid, 2009), is rare in Central America (Fujita & Kunz, 1984).

Their hibernacula are seasonally different (Fujita & Kunz, 1984) and they can roost in small groups in caves, mines, and other man buildings (Davis 1964; Reid, 2009), but in spring they have maternity colonies frequently found in barns, trees, caves and rock crevices (Lane, 1946; Humphrey et al., 1976; Fujita & Kunz, 1984). Their forage behavior indicates that is frequent over waterways and forest edges (Fujita & Kunz, 1984; Reid, 2009).

Status and conservation. Populations of *P. subflavus* in eastern North American are threatened because they are highly susceptible to the white-nose syndrome (WNS) (Bernard & McCracken, 2017; Leivers et al., 2019) and this is one of the reasons that is considered as VU (Vulnerable) by the IUCN (Solari, 2018).

DISCUSSION

Rinker (1948) checked three unidentified specimens preserved in alcohol in the collection of the Division of Mammals, University of Michigan Museum of Zoology (catalogue numbers as follows: 55863, 55864, 55865) that were collected on 23 May 1924 on the Jilamo Farm, Dakota Division, Tela District, of the United Fruit Company in Atlántida, northern Honduras. The three bats were pregnant females and represented at that time, the first record of *Perimyotis subflavus* in Honduras and the southernmost record of the species. After these records, there was no further information about the species in Honduras. McCarthy et al. (1993) described a new record of a male of *P. subflavus* at 16.5 km (by road) SSW Dulce Nombre de Culmí in Olancho, eastern Honduras. The record mentioned by them was done by W.J. Bleier on 22 July 1971



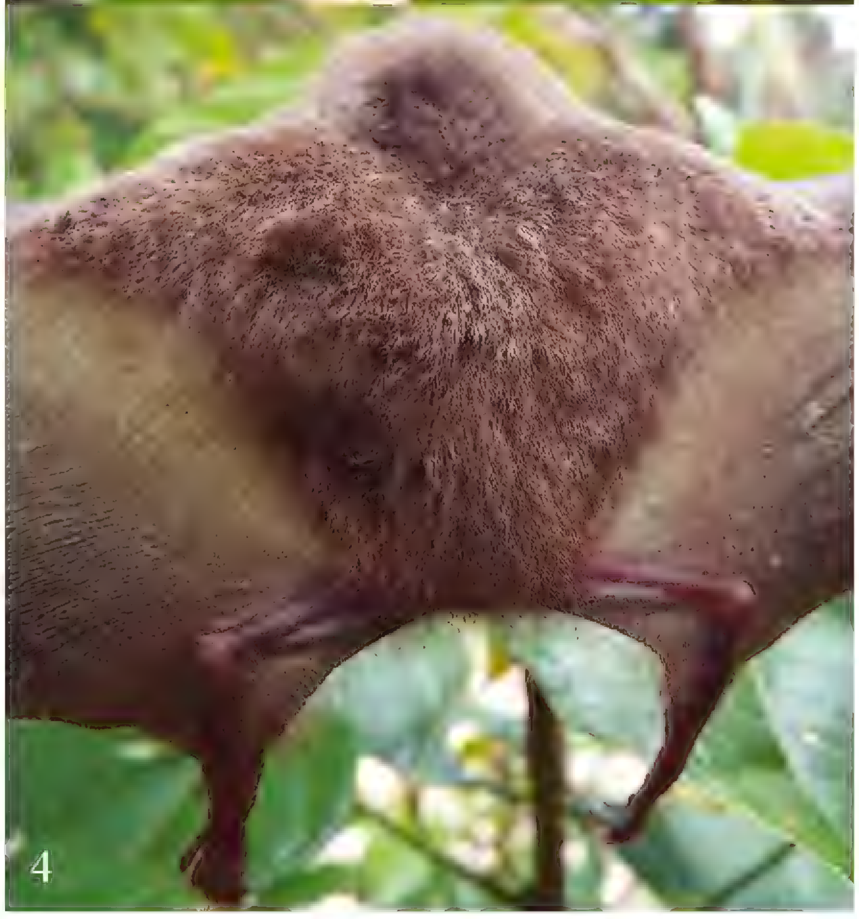
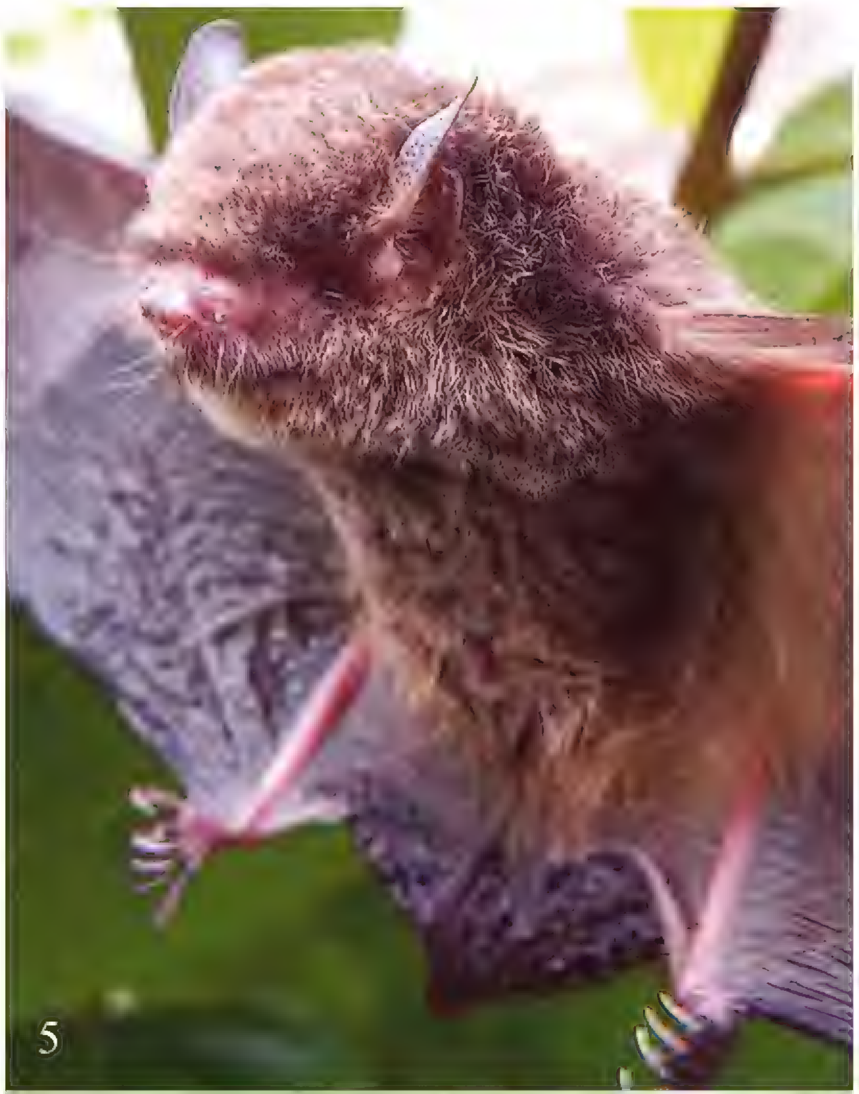


Figure 3. Frontal view of a male of *Anoura geoffroyi* captured in PANACAC during the night of 31 October 31, 2017. Figure 4. Note the reduced and heavily furred uropatagium.



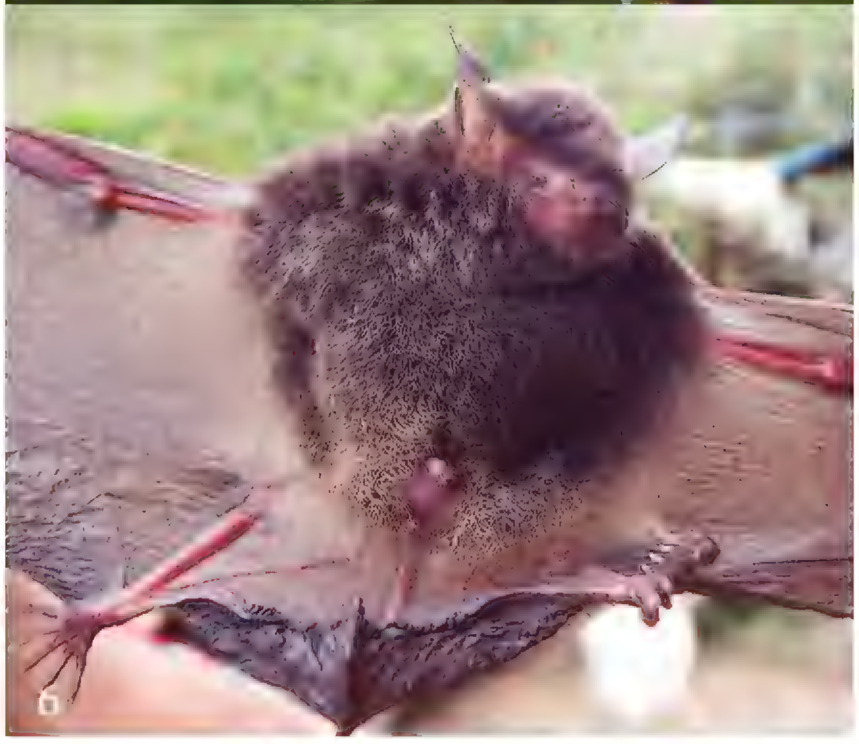


Figure 5. Frontal view of a male of *Perimyotis subflavus* captured in PANACAC in western Honduras during the same night with *A. geoffroyi*. Figure 6. Lateral view of the same specimen, note that the tragus was curved with a rounded tip.

Figure 7. Teaching the importance of the conservation of bats to children in the municipality of Florida, Copán, western Honduras.

and extended the range of this species approximately 186 km ESE from Jilamo, Atlántida. Considering the records presented here, there are only four records of *P. subflavus* in Honduras and the last record of the species was 46 years ago. Currently, the advance of white-nose syndrome is affecting a large part of its eastern distribution in North America, and the population may decrease up to 45% over the next 15 years (Solari, 2018). Additionally, Leivers et al. (2019) mentioned that *P. subflavus* is currently under review for listing under the Endangered Species Act of the United States Fish and Wildlife Service. The records of *P. subflavus* in the cave El Ermitaño represent the only known record of the species in Copán, the westernmost record and the highest altitudinal record of the species in the country, and considering Ortega & Alarcón (2008) iy is the first time that *P. subflavus* has been found roosting together with *A. geoffroyi*. In Central America, the southernmost record of the species is in Somoto Canyon in Madríz in northern Nicaragua, approximately 160 km from Dulce Nombre de Culmí in Olancho (Medina-Fitoria et al., 2015).

The two individuals of *P. subflavus* captured in PANACAC are slightly larger than those recorded in Atlántida (Rinker, 1948) and the individual of Olancho (McCarthy et al., 1993). This first report of *P. subflavus* roosting in the cave El Ermitaño is in agreement with Whitaker (1998) because we did not find any females roosting together with males (generally they roost alone). Even though *P. subflavus* enter the hibernaculum in late July-October and leaves their roosts at the beginning of April (Fujita & Kunz, 1984), it is unknown how torpor varies in the neotropical species (Morrison & McNab, 1967).

McCarthy et al. (1993) also presented the first records of *A. geoffroyi* in Honduras: Yuscarán in El Paraíso, southeastern Honduras; Talanga in Francisco Morazán, central Honduras; La Esperanza in Intibucá and Nueva Ocotepeque in Ocotepeque, western Honduras; and Catacamas, Juticalpa, and Dulce Nombre de Culmí in Olancho, eastern Honduras. Additionally, in the GBIF.org (2019) database there are 30 more records in the country, and the last record of the species was in 2004. Moreover, Mora et al. (2018) reported *A. geoffroyi* as a common species and considered its occurrence in Honduras with no further information of the species. Our records are in accordance with Reid (2009) in which the species roosts in caves but its ecology is still unknown in Honduras.

The records *P. subflavus* and *A. geoffroyi* in PANACAC are the first ones in the protected areas, also are the first ones in the department of Copán in western Honduras. Even though PANACAC might represent an interesting site to study the biodiversity of the highlands of western Honduras, it has been affected by the extension of crops and cattle. Considering the conservation activities mentioned by Solari (2018), a good forest management, including the protection of the core zone of the protected area, could help to keep stable populations by increasing areas for roosting and foraging for *P. subflavus* (and indirectly to the conservation of *A. geoffroyi* because they shared the same roosting site). In Nicaragua, *P. subflavus* is only known from one record and is considered very rare with a restricted distribution, and *A. geoffroyi* is considered a rare species which is known only in highlands (Medina-Fitoria et al., 2015). Another species that shares the same roosting site with both species is *Diphylla ecaudata* and has a conservational interest because Mora et al. (2018) considered it widely distributed in Honduras excluding the western region of Honduras.

As well as in Santa Bárbara (Turcios-Casco et al., 2019), people set fire to caves trying to get rid of the bats because they considered that all of them are "vampiros" (Spanish name to vampire), and they think that all bat species are hematophagous (these problems are known as human-vampires and are affecting populations of many species in western Honduras). Medina-Fitoria et al. (2017) mentioned that 10.7% of the bat species in Honduras were considered threatened in 2012, and due to the previous reasons, we strongly recommend educational activities (Fig. 7) to avoid such practices not only in PANACAC but in all the country.

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Two morphotypes of tri-spine horseshoe crab, *Tachypleus tridentatus* (Leach, 1819) (Xiphosura Limulidae) in Indonesia and implications for species identification

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ABSTRACT Of the four extant species of horseshoe crabs in the world (Xiphosura Limulidae), Indonesia have three species, i.e., *Tachypleus tridentatus* (Leach, 1819), *T. gigas* (O.F. Müller, 1785) and *Carcinoscorpius rotundicauda* (Latreille, 1802). The species identification based on morphology of especially the females of the two *Tachypleus* species can be difficult. This study aimed at evaluating morphological characters used in species determination of *T. tridentatus* and *T. gigas*. Two morphological characters for separating the two species are the number and position of immovable spines and the spinnerets on the opisthosomatic carapace. The study was conducted in Balikpapan coastal area in Indonesia. Two morphotypes of *T. tridentatus* were found. Of the 120 collected specimens, 13.33% had one immovable spine, while 86.67% had three immovable spines on the opisthosomatic carapace. The two morphotypes were found in both males and females. DNA barcoding of both males and females with two morphotypes confirmed that the specimens were *T. tridentatus*. Thus, three immovable spines at opisthosoma can still be used as a morphological characters for *T. tridentatus* identification, but another morphotype with only one spine is present. This makes the distinction between the females of the two *Tachypleus* species more difficult. However, spinnerets on the dorsal opisthosoma can still be used to separate them.

KEY WORDS Horseshoe crab; morphogenetics; molecular identificatication; species complex.

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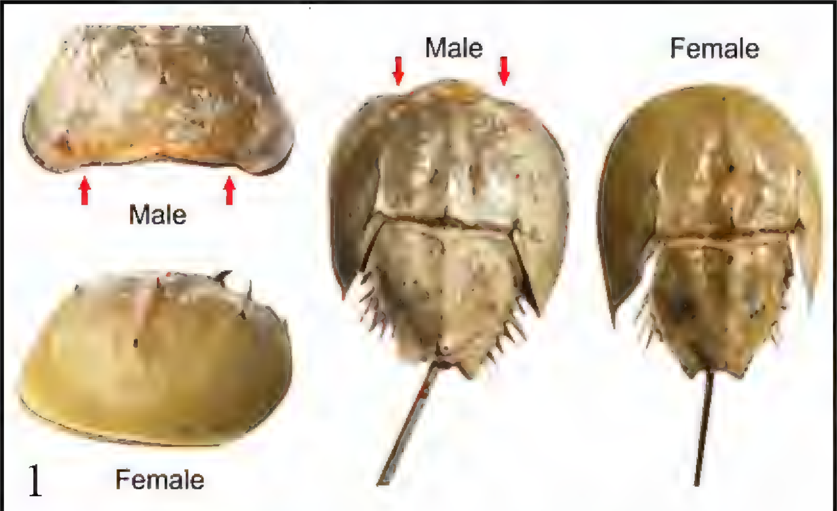
INTRODUCTION

The four species of extant horseshoe crabs are the American horseshoe crab, *Limulus polyphemus* (Linnaeus, 1758), restricted to Atlantic waters (Walls et al., 2002) and the three Asian horseshoe crabs (*Carcinoscorpius rotundicauda* (Latreille, 1802), *Tachypleus gigas* (O.F. Müller, 1785), and

Tachypleus tridentatus (Leach, 1819) (Lee & Morton, 2005; Sekiguchi & Shuster, 2009). All three species of Asian horseshoe crabs can be found in Indonesian coastal waters, distributed around Sumatra, Java, Kalimantan and Sulawesi (Rubiyanto, 2012; Mashar et al., 2017; John et al., 2018a, b; Vestbo et al., 2018).

The conservation status of *L. polyphemus* is vulnerable (VN) and the species has been intensively studied compared to *C. rotundicauda*, *T. gigas*, and *Tachypleus tridentatus*. Recently, *T. tridentatus* changed to endangered (EN) conservation status (IUCN, 2019) from data deficient (DD) (IUCN, 2015). The remaining two species of horseshoe crabs (*C. rotundicauda* and *T. gigas*) are categorised as data deficient conservation status (DD) (IUCN, 2015).

Since the number of studies of Asian horseshoe crabs are limited and their current geographic distribution is not fully known, it would be valuable to involve local communities living near the habitats of the horseshoe crabs in sampling and monitoring.



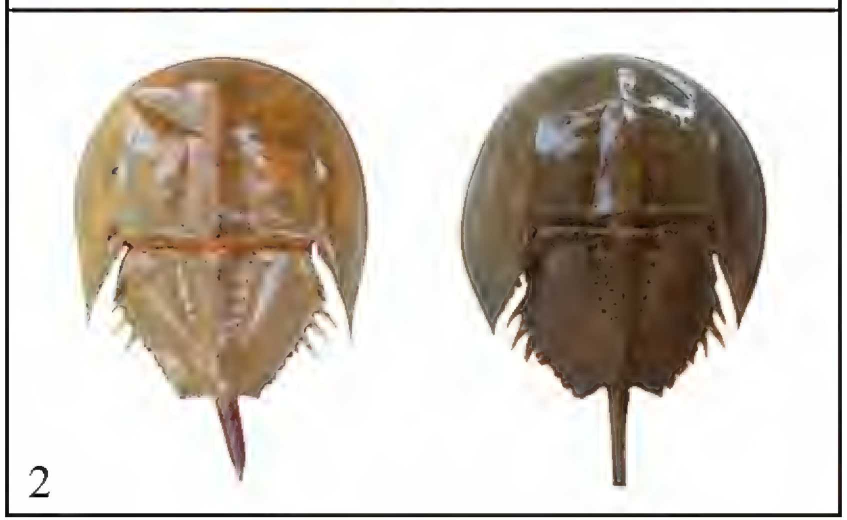


Figure 1. Male and female of *Tachypleus tridentatus* collected from Balikpapan coastal area, Indonesia. The prosoma in the male showed two clear symmetrical indentation as indicated by arrows. Figure 2. Dorsal view of female *T. tridentatus* (left) and *T. gigas* (right) showing smooth curves of prosoma which renders these two species as the same species.

However, in order to do this, knowledge on how to differentiate between the three Asian species using morphological characters is required. Determining sex for *T. tridentatus* can be done by abscertaining the presence of two clear symmetrical indentations in prosoma for males and their absences of it for females (Fig. 1). The indentations can be used to distinguish between male *Tachypleus tridentatus* and *T. gigas*. However, the frontal margin (smooth curve of prosoma) in the female of the two species look the same (Fig. 2).

Monophyly in the genus *Tachypleus* is strongly supported by phylogenetic analysis using molecular data (Obst el al., 2012), and the two species of *Tachypleus* are charactarized by a triangular telson in cross-section with a dorsal keel and a ventral groove and can easily be distinguished from the mangrove horseshoe crab *Carcinoscorpius rotundicauda* that has instead a subtriangular telson with round ridges in cross-section. Also, *C. rotundicauda* is small-sized compared to the two *Tachypleus* species (Yamasaki, 1988). For *T. tridentatus*, morphological characters used in previous studies are three immovable spines located on the dorsal posterior margin of ophisthosoma and spinnerets scattered on the dorsal opisthosomatic carapace (Pocock, 1902; Waterman, 1958; Yamasaki, 1988; Liao et al., 2002; Chiu & Morton, 2003). The common name tri-spine horsehoe crab used for *T. tridentatus* actually refers to the presence of the three immovable spines. The morphological characters used for identifying *T. gigas* is the presence of only one median immoveable spine pointed posteriorly, and a smooth opisthosomatic carapace except for the cardiac region (Yamasaki, 1988). This study aimed at evaluating the morphological characters used to differentiate between *T. tridentatus* and *T. gigas* and to provide a practical guide for species determination in voluntary monitoring by local communities living near the horseshoe crab habitats.

MATERIAL AND METHODS

Study area and specimen collection

The study was conducted in at fish landing sites of Balikpapan coastal area, Indonesia (Fig. 3). Horseshoe crabs were collected with help from local fishermen using gillnet and trawl-like fishing gear. A total of 105 individuals of *T. tridentatus* were collected from 1 January to 31 March 2018 and 15 additional individuals were obtained from 23 October to18 November 2019. Two specimens of *Tachypleus gigas* were collected for morphological comparison with *T. tridentatus.*

Morphological identification and DNA barcoding

All collected specimens were identified morphologically following Pocock (1902) and Yamasaki (1988). Hemolymph from four specimens of *T. tridentatus* were sampled to validate the species identification using molecular approach. The four specimens included males and females with one and three spines on the posteriormost dorsal opisthosoma. Genomic DNA was extracted using the GeneAID Kit as instructed from the supplier. A cytochrome c oxidase I (CO1) mitochondrial gene fragment were amplified using the primer pairs designed by Nurlisa Alias Butet (2013; unpublished data). PCR amplification was performed in a SEDI Thermo Cycler RM G with 5 µl genomic DNA, 4.5 µl H2O, 12.5 taq polymerase 12.5 µl, CO1 forward primers 1.5 µl, reverse CO1 primers 1.5 µl. Stages of PCR include pre denaturation (95ºC for 5 min), denaturation (94ºC for 45 sec), annealing (54ºC for 1 min), elongation (72ºC for 1 min) and post elongation (72ºC for 1 min). The stages of denaturation, annealing and elongation were carried out in 35 cycles. The quality of PCR products were tested on 1.2% agarose gels, and those with amplified products were sent to sequencing facility by Genetika Science Indonesia. Forward and reverse nucleotide sequences were aligned with ClustalW in MEGA version 7 software (Kumar et al., 2016). The aligned sequences were blasted in GenBank using the National Center for Biotechnology Information (NCBI) (Zhang et al., 2000, Morgulis et al., 2008) for species identification and comparison.

RESULTS AND DISCUSSIONS

Of the 120 collected specimens of *T. tridentatus* from Balikpapan coastal waters, 13.33% of them had one mid-dorsal immovable spine on the posterior margin of the opisthosomatic carapace, while 86.67% of them had three immovable spines in the posterior of opisthosoma. The two morphotypes were found in both males and females (Fig. 4).

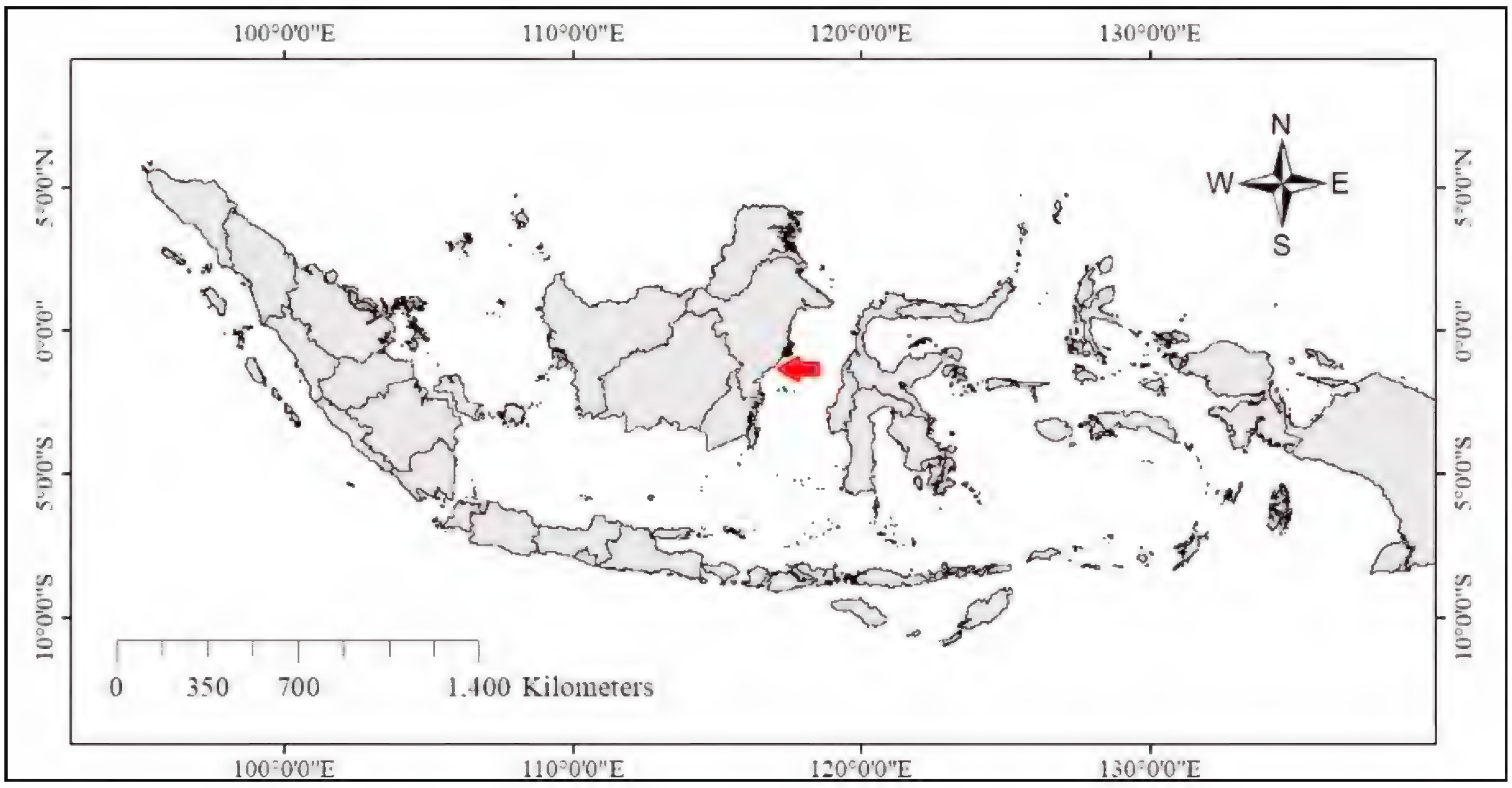


Figure 3. Sampling location in Balikpapan coastal area, Indonesia as indicated by the red arrow.

Successful PCR and sequence data was obtained from four *T. tridentatus* representing two males and two females of the two morphotypes. Blasting of 551–593 bp long CO1 gene fragments of all four samples showed 99% similarity with sequences of *Tachypleus tridentatus* in the NCBI database (access code JQ739210.1, FJ860267.1, and U09387.1). Consequently, the presence of the three immovable spines at the posteriormost opisthosoma of *T. tridentatus* could be potentially be used as a morphological character for species identification with precaution, although it was used succesfully in many previous studies (Pocock, 1902; Waterman, 1958; Yamasaki, 1988; Liao et al., 2002; Chiu & Morton 2003; Muslihah, 2004; Yang & Ko, 2015; Dolejš & Vaňousová, 2015; Hu et al., 2015). However, the presence of spinnerets on the dorsal opisthosomatic carapace of *T. tridentatus* compared to *T. gigas* with a smooth surface except for the cardiac region was consistently species-specific (Figs. 5, 6).

This study was based on specimens collected in the Balikpapan coastal area, Indonesia. It would be interesting to study possibly variability in the number and position of posterior immovable spines in *T. tridentatus* from other geographic areas to investigate their variation, either general or a local variation. A previous study that used morphometric analysis of body shape in three species of horseshoe crabs failed to show regional intraspecific variation in females of *C. rotundicauda* and *T. gigas*, however males of *C. rotundicauda* did show variation (Faurby et al., 2011).

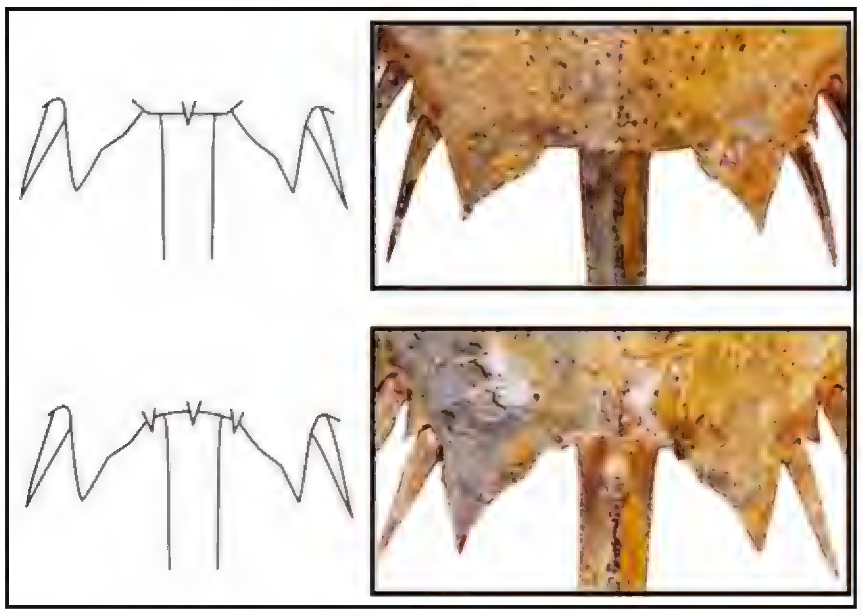
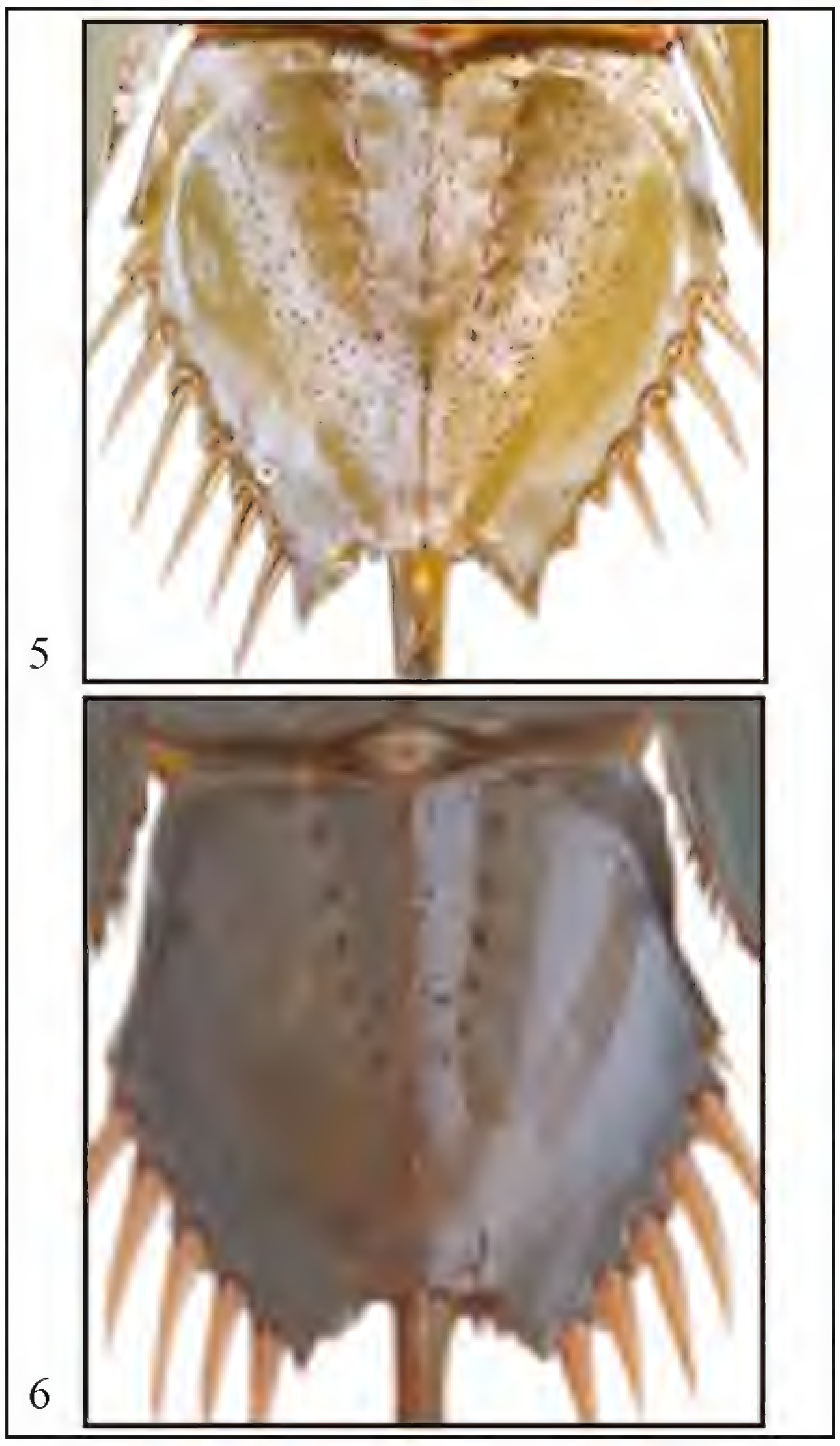


Figure 4. Two morphotypes of *Tachypleus tridentatus* from Balikpapan coastal area, Indonesia. The dorsal posteriormost opisthosoma carries either one or three spines.



Figures 5, 6. Comparison of the dorsal opisthosoma of *Tachypleus tridentatus* (Fig. 5) and *T. gigas* (Fig. 6) from Balikpapan coastal area, Indonesia.

CONCLUSIONS

It can be concluded that the distribution pattern of spinnerets on the dorsal opisthosomatic carapace could be potential to be used as a morphological character to distinguish between *T. tridentatus* from *T. gigas*, while the number and position of the immoveable spines as a brace character.

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Description of *Alvania rominae* n. sp. from the Mediterranean Sea (Mollusca Gastropoda Rissoidae)

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ABSTRACT A new Mediterranean species of the genus *Alvania* Risso, 1826 (Gastropoda Rissoidae) is described: *A. rominae* n. sp. All examined specimens are from the Ionian Sea. It is compared with the most similar congeners from the Mediterranean Sea: *A. lineata* Risso, 1826 and *A. settepassii* Amati et Nofroni, 1985, with which it is sympatric, and *A. schwartziana* Brusina, 1866, *A. elisae* Margelli, 2001, *A. bartolinorum* Amati et Smriglio, 2019 and *A. zaraensis* Amati et Appolloni, 2019.

KEY WORDS Gastropoda; Rissoidae; *Alvania*; new species; Mediterranean Sea, taxonomy.

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INTRODUCTION

The genus *Alvania* Risso, 1826 (Gastropoda, Rissoidae) includes a group of small marine species living from the lower intertidal to bathyal depths, mostly on the continental shelf, where they are often associated with algal facies (e.g. Tringali, 2001; Gofas & Oliver, 2011; Amati, 2012), with scarce representatives in deeper waters down to 4700 m depth (Bouchet & Warén, 1993). They feed on diatoms, dinoflagellates, and detritus, with the deep-sea species being presumably selective deposit feeders (Ponder, 1985). The genus, as currently conceived, includes about 250 species (MolluscaBase, 2020) and is distributed almost worldwide (northeastern Atlantic and Mediterranean Sea, northwestern Atlantic, Caribbean, eastern Pacific, Indo-West Pacific, temperate Australia and South Africa: Ponder, 1985). This is one of the nominally most diverse genera of gastropods and is particularly species-rich in the Mediterranean Sea, with over 70 recognized species. In the Mediterranean Sea, *Alvania* comprises species of small to medium size for the family (from 1 mm length of *A. maximilicutiani* Scuderi, 2014, to 7 mm length of *A. mamillata* Risso, 1826: Scuderi, 2014; Amati et al., 2017). The shell is ovate-conical, generally with axial and spiral elements forming a delicate to robust clathrate sculpture, a continuous peristome, and a variable colouration.

The genus *Alvania* includes several species groups defined morphologically, as for instance the complexes of *A. lineata* Risso, 1826 (Amati et al., 2019), *A. dictyophora* (Philippi, 1844) (Amati & Smriglio, 2016), *A. subcrenulata* (Bucquoy, Dautzenberg et Dollfuss, 1884) (Amati, 2014), *A. cimex* (Linnaeus, 1758) (Amati et al., 2017), *A. rudis* (Philippi, 1844) (Amati et al., 1987) and *A. scabra* (Philippi, 1844) (Amati et al., 2020). Among them, the *A. lineata*-complex includes some 23 recognised extant species (Amati et al., 2019), all with non-planktotrophic development (and paucispiral protoconch), except for *A. discors* (Allan, 1818) which has a planktotrophic larval stage (and multispiral protoconch). For a description and a recent revision of the *A. lineata* group we refer to Amati et al. (2019). Traditionally, the taxonomy of Mediterranean rissoids has been based almost exclusively on shell characters, whose puzzling variation has often caused uncertainty about the status of some of these taxa. Admittedly, studies integrating multiple sources of information (teleoconch, protoconch, soft parts morphology and colour pattern, radula, and particularly, genetics) would certainly be crucial in assessing their taxonomy. However, in most cases, the availability of large samples and the comparative study of type material provide enough important data to improve current taxonomic knowledge.

Several specimens of the *A. lineata* complex from the Ionian Sea are morphologically distinct from all other known members and are described herein as a new species: *A. rominae* n. sp.

MATERIAL AND METHODS

The samples studied here are stored in public and private collections, as detailed below (see Abbreviations and acronyms). Photographs have been taken with a Sony Cyber-Shot digital camera mounted on a Kyowa KBS stereomicroscope, edited with the Combine-Z software (Hadley, 2006). The adopted rissoid taxonomy is after MolluscaBase (MolluscaBase, 2020: accessed through the World Register of Marine Species, WoRMS). Measurements were taken on a random sample of 15 specimens (full-grown intact adults) and are reported in Table 1.

ABBREVIATIONS AND ACRONYMS. AF: Angelo Fiorita collection (Porto Cesareo, Lecce, Italy); AR: Alessandro Raveggi collection (Firenze, Italy); AV: Angelo Vannozzi collection (Roma, Italy); BA: Bruno Amati collection (Roma, Italy); CS-PM: Carlo Smriglio-Paolo Mariottini collection (Roma, Italy); DS: Danilo Scuderi collection (Scordia, Catania, Italy); DT: Daniele Trono collection (Copertino, Lecce, Italy); EQ: Ermanno Quaggiotto collection (Longare, Vicenza, Italy); IN: Italo Nofroni collection (Roma, Italy); lv: live collected specimens; MCZR: Museo Civico di Zoologia (Roma, Italy); MNHN: National Museum of Natural History (Paris, France); MO: Marco Oliverio collection (Roma, Italy); SB-MS: Stefano Bartolini-Maria Scaperrotta collection (Firenze, Italy); sh: empty shell(s); WR: Walter Renda collection (Amantea, Cosenza, Italy).

RESULTS

Systematics

Classis GASTROPODA Cuvier, 1795
Subclassis CAENOGASTROPODA Cox, 1960
Superfamilia RISSOOIDEA Gray, 1847
Familia RISSOIDAE Gray, 1847
Genus *Alvania* Risso, 1826

Type-species: *Alvania europea* Risso, 1826: 142, pl. IX, fig. 116 = *Alvania cimex* (Linnaeus, 1758) (*Turbo*), by subsequent designation Nevill, 1885: 105.

Alvania rominae n. sp. (Figs. 1–22; Table 1)
https://zoobank.org:act:421E1F98-B6BE-4BFC 870B-B8D1DB71B227

TYPE MATERIAL. Holotype MNHN-IM-2000-35744, H 3.5 mm, W 2.05 mm (Figs. 2–4, 14, 15, 22); 11 paratypes (DT), 1 paratype MCZR-M-TYPE00093/P; 1 paratype (BA), 1 paratype (MO), 1 paratype (AF); 1 paratype (WR); 1 paratype (AV); type locality: Gallipoli, Lecce 40°00'95"N 17°55'32"E, 58 m depth, Ionian Sea.

OTHER EXAMINED MATERIAL. *Alvania rominae* n. sp. Italy: Otranto, Lecce 40°13'85"N 18°51'35"E, 35 m depth, VIII.2004, 10 sh (DT); S. Isidoro, Lecce 40°08'28"N 17°49'13"E, 53 m depth, VIII.2008, 8 sh (DT); S. Isidoro, Lecce 40°08'28"N 17°49'13"E, 53 m depth, 29.VII.2018, 2 sh (DT); Porto Cesareo, Lecce 40°11'48"N 17°47'08"E, 40 m depth, III.2019, 2 sh (DT).

Alvania elisae Margelli, 2001 (Fig. 28): Type material: 1 paratype, Capraia Island, 2 –15 m depth (CS-PM, ex M.A. Fontana Angioy coll., Rome); Italy: Capri Island, unspecified depth, 7 sh (MCZR–M–30060); Elba Island, Capo di Fonza, 25 m depth, 80 sh (EQ), 7 sh (BA); Elba Island, Capo di Stella, 20 m depth, 13 sh (EQ); Elba Island, 3 sh (MO); Capraia Island, P.ta della Fica, 24 m depth, 3 sh (DT).

Alvania lineata Risso, 1826 (Figs. 29–51): Spain: Fuengirola, 30 m depth, VIII.1985, 45 sh (BA); Malaga, 5–10 m depth 11.XI.2009, 30 sh (BA); Tunisia: Gulf of Gabès, Kerkennah, 1974, 24 sh (BA); Gulf of Gabès, Kerkennah, loc. Sidi youssef, VII.2015, 200 sh (BA); Corsica, Barcaggio, 20 m depth, 4 sh (DT); Sardinia: San Teodoro, 1 sh (BA); Cala Gonone, Dorgali, 1 m depth, VIII.2010, 25 lv (BA), 2–4 m depth, VIII.2010, 61 sh (BA); Maddalena Island, 1989, 24 m depth, 1 sh (BA); Golfo Aranci, 1985, 3 sh (BA); Oristano, VIII.1978, 4 sh (BA); Sicily: Salina Island, 35 m depth, VII.2002, 500 sh (BA); Levanzo Island, Punta Altarella 31 m depth, 3.VI.1991, 6 sh (BA); Marettimo Island, Egadi, 19 sh (BA); Magnisi, Beached, legit Oberling (13.III.1970), 35 sh, (BA); Portopalo di Capo Passero, 1 sh (BA); Lampedusa Island, Capo Grecale, VII.2009 50 m depth 10 sh (BA); Cannizzaro, Catania, 35–43 m depth, 61 sh (BA); Ognina, Siracusa, 13 sh (BA) 1984, washing algae, 24 lv (BA); Lampedusa Island, 30 m depth, 53 sh (BA); Lampedusa Island, Cala Calandra 30 m depth, 30.IV.1991, 46 sh (BA); Vendicari Island, 28 m depth, 23 sh (BA); Ragusa, Roventa Shoal, 27 m depth, VI.1989, 8 sh (BA); Marettimo Island, Egadi I., 10 sh (BA); Linosa Island, P.ta Calcarelle, 36 m depth, 3 sh (DT); Stretto di Messina, 19 m depth, 5 sh (DT); Malta: Malta Island, beached bioclastic sand, 1 sh (BA); Italy: Giglio Island 27–36 m depth, 45 sh (BA); Capraia Island 200–280 m depth, 1979, 1 sh (BA), 140–180 m depth, 1978, 16 sh (BA); Capraia Island, P.ta della Fica, 24 m depth, 4 sh (DT); Secca di Torre Flavia 26 m depth, 1986, 64 sh (BA); Secche di Tor Paterno, Rome, 30 m depth, 1.X.1988, 4 sh (BA), 45 m depth, 18 sh (BA); Santo Stefano Island, 40 m depth, 14 sh (BA); Ventotene Island, 1979, 25 sh (BA); Torre Astura, Rome, 1977, 1 sh (BA); San Felice Circeo, Latina, 30 m depth, 10 sh (BA), 4–6 m depth, 43 sh (BA-MO), 20 m depth, 8 sh (DT); Pozzano, Reggio Calabria, 40 m depth, VIII.1986, 1 sh (BA); Scilla, 41 m depth, 16.XII.2006, legit Marconcini, 48 sh (IN); Gallipoli, Lecce, 2,5 m depth, 1 sh (DT); Nardò, Lecce, loc. S. Caterina, 30 m depth in the cave, 3 sh (DT), 18–23 m depth, 12 sh (DT); Nardò, Lecce, loc. Torre Inserraglio, 20 m depth, 13 sh (IN), 20 m depth, 28 sh (DT); Porto Cesareo, Lecce, tide pools, VIII.1976, 11 sh (IN), VIII.1988, 20 sh (IN); Secca di Pellaro, 25 m depth, 18 sh, (DT); Castro, Lecce, 23 m depth, 10 sh (DT); Croatia: Umag, beached bioclastic sand, 73 sh (BA); Umag, 1978, 7 sh (BA); San Lorenzo, 5 sh (BA); Slovenija: Portoroz, beached bioclastic sand, 1 sh (BA); Greece: undefined locality, 29 sh (BA); Crete, 34 sh (MCZR-M-30127); Crete, beached bioclastic sand, 5 sh (BA); Mediterranean Sea, undefined localities, 75 sh (MCZR-M-22149).

Alvania settepassii Amati et Nofroni, 1985 (Figs. 23, 24): Type material: holotype (MCZR-M-TYPE00004/H) and 42 paratypes, Secche di Tor Paterno, 45 m depth (BA); 69 paratypes Civitavecchia, 25–30 m depth, (BA); Italy: Giglio Island, 27–30 m depth, 16 sh (BA); S. Stefano Island, 40 m depth, 1 sh (BA); Torvaldaliga, Civitavecchia, 20–22 m depth, 250 sh (CS-PM); Secche di Torre Flavia, Ladispoli 26 m depth 1986, 3 sh (BA); Torre Astura, beached, 3 sh (BA); Nettuno, beached, 1982, 1 sh (BA); San Felice Circeo, Latina, 4–6 m depth, 69 sh (BA-MO), 20 m depth, 4 sh (DT); Nardò, Lecce, loc. S. Caterina, 18–23 m depth, 6 sh (DT); Nardò, Lecce, loc. Torre Inserraglio, 20 m depth, 13 sh (IN), 20–22 m depth, 44 sh (DT); Secca di Pellaro, 25 m depth, 4 sh (DT); Gallipoli, Lecce, 30 m depth, 4 sh (DT); Castro, Lecce, 23 m depth, 11 sh (DT); Porto Cesareo, Lecce, 30 m depth, 4 sh (DT); Nardò, Lecce, loc. Torre Uluzzo, 29 –34 m depth, 2 sh (DT); Sicily: Vendicari Island, 28 m depth, 1 sh (BA); Croatia: Lastovo Island 38 m depth, 21 sh (BA); Greece: Crete, 960 m depth, 3 sh (AP).

Alvania schwartziana Brusina, 1866 (Fig. 25): Type material: 4 syntypes, Zadar, Croatia (MCZR-M-22326, Monterosato coll. ex Brusina). Croatia: Zadar and Pag, 8 sh (BA); Starigrad Paklenica, Zadar, 6 m depth, 29 sh (EQ); Dalmatia, 40 m depth, 2 sh (DT); Italy: Chioggia, Venice, 20 m depth, 2 sh (EQ).

Alvania bartolinorum Amati et Smriglio, 2019 (Fig. 26): Type material: holotype, (MNHN-IM-2000-27706) and paratypes (BA, CS-PM, SB-MS, AR, EQ), Krk Island, Croatia. Croatia: Krk Island, 54 m depth, IX.2008, 4 sh (AR), 252 sh (SB-MS), 16 sh (EQ); Krk Island, Giapni Potok, 54 m depth, 23 sh (AR).

Alvania zaraensis Amati et Appolloni, 2019 (Fig. 27). Type material: holotype, (MCZR-M-22152/H) and 14 paratypes, Zadar, Croatia (MCZR-M-22152/P).

DIAGNOSIS. Medium sized rissoid height 2.9–3.6 mm with axial sculpture of 8–12 ribs interrupted at the periphery on the last whorl; spiral sculpture of 9–11 non-equidistant spiral cords on the last whorl, of which 5 above the aperture and with variable chromatic pattern.

DESCRIPTION OF THE HOLOTYPE. Shell (Figs. 2–4; 14, 15, 22) solid, oval-conical, of medium size for the genus, height 3.5 mm, width 2.05 mm, H/W ratio 1.707. Protoconch (Fig. 15) paucispiral, globose, of 1.3 whorls, height 0.35 mm, nucleus diameter 0.15 mm, first half whorl diameter 0.25 mm, maximum diameter 0.40 mm; sculpture of a dozen slightly wavy spiral threads, partially anastomized. Teleoconch of 4.25 slightly convex whorls, suture impressed, especially in the first whorls. Axial sculpture of 9 ribs interrupted at the periphery on the last whorl, as wide as the interspaces or slightly narrower; always orthocline on the first two whorls, from slightly opisthocline to slightly prosocline on the others. Spiral sculpture of 11 non-equidistant spiral cords on the last whorl, of which 5 above the aperture, one sutural, and 5 more spaced, on the base; two cords (III and V) starting immediately after protoconch/teleoconch boundary, followed by cord I, IV and finally II. Basal cords decreasing in size and strength, last one barely noticeable. Microsculpture of spiral minute threads and weak growth lines. Umbilical fold absent. Aperture large, pyriform, height 1.5 mm, H/Ha ratio 2.333. Outer lip sharp, with large prosocline varix, without fine elongated internal teeth. Colour yellow-orange background, with darker spiral cords. Base, internal aperture and varix whitish. Operculum and soft parts unknown.

VARIABILITY. Paratypes variation (see also Table 1): shell height 2.9–3.6 mm, width 1.75–2.1 mm, H/W ratio 1.611–1.846. Protoconch (Figs. 17, 18, 20) paucispiral, globose, of 1.25–1.5 whorls, height 0.325–0.40, nucleus diameter 0.125–0.150, first half whorl diameter 0.225–0.275 mm, maximum diameter 0.387–0.425 mm. Teleoconch whorls 3.8–4.25; axial sculpture of 8–12 ribs; spiral cords on the last whorl 9–11, of which 5 above the aperture, one sutural, and 3–5 more spaced, on the base. Aperture height 1.25–1.6 mm, H/Ha ratio 2.250–2.560. Outer lip sharp, with large prosocline varix, often with 7–8 fine elongated internal teeth. Colour whitish-yellowish to brown-beige background with pinkish hue; usually first whorls darker brown-orange, pink-violet aperture, and darker spiral cords; brown or whitish-yellowish monochrome shells not rare.

DISTRIBUTION AND BIOLOGY. Examined material from the Ionian Sea (Italy): Gallipoli, Porto Cesareo, S. Isidoro, Otranto. Empty shells in 35–58 m depth. (Fig. 1). Sympatric in the Ionian Sea with *A. lineata* and *A. settepassii*.

ETYMOLOGY. After Mrs. Romina Leo, wife of one of the authors (Daniele Trono).

REMARKS. The examined materials showed a negligible morphological variation, except for the variable chromatic pattern of the shell, with monochromatic brown or whitish-yellowish shells not rare. Almost half of the specimens examined had some elongated teeth inside the outer lip. Other species are characterised by an inconsistent presence of teeth, as e.g., *A. mamillata* Risso, 1826, *A. dictyophora* (Philippi, 1844), *A. hallgassi* Amati et Oliverio, 1985 and *A. desabatae* Amati et Smriglio, 2016 (Amati et al., 2020). Micali et al. (2005: 23, fig. 2) figured as *Alvania* sp. a shell from Tremiti Islands similar to *A. rominae* n. sp. but more likely belonging to *A. bartolinorum*. That specimen is stated to be conspecific with samples listed by Chiarelli & Micali (2003: 16) from Vela Luka (Croatia). Instead, the two specimens from

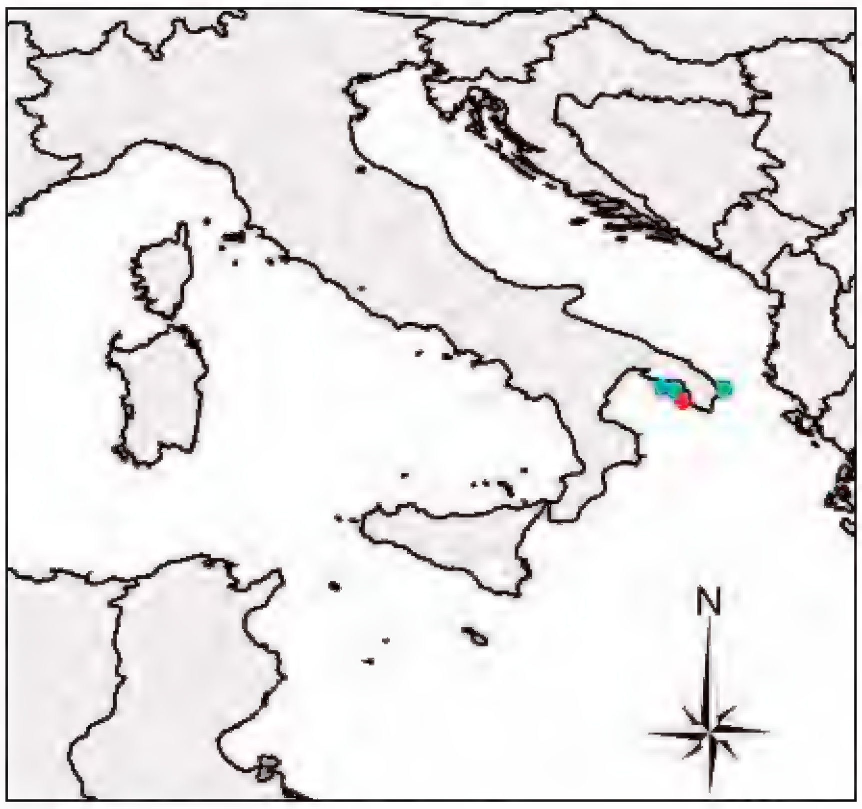


Figure 1. Distribution of *Alvania rominae* n. sp., based on the material examined (red 'type material' and light-blue dots 'other examined material').

Teleoconch	1	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	Min-max	Mean	Std
Height	3.25	2.90	**3.50**	3.55	3.60	3.55	3	3.20	3.35	3.25	3	3.02	3.20	3	3.05	2.90- 3.60	3.228	0.235
Width	1.95	1.80	**2.05**	2	1.95	2.10	1.85	1.85	1.90	1.85	1.75	1.80	1.80	1.75	1.75	1.75-2.10	1.877	0.112
Aperture height	1.4	1.25	**1.5**	1.45	1.6	1.55	1.25	1.25	1.35	1.35	1.25	1.3	1.3	1.25	1.27	1.25-1.60	1.355	0.119
Height/width ratio	1.666	1.611	**1.707**	1.775	1.846	1.690	1.621	1.729	1.763	1.756	1.714	1.677	1.777	1.714	1.742	1.611-1.846	1.719	0.062
Height/aperture height ratio	2.321	2.320	**2.333**	2.448	2.250	2.290	2.400	2.560	2.481	2.407	2.400	2.323	2.461	2.400	2.401	2.250-2.560	2.386	0.082
N° of whorls	4.2	4	**4.25**	4.2	4	4	4.1	4.1	4.25	4.2	4.1	3.8	4.1	4	4	3.8-4.25	4.087	0.123
N° axial ribs on last whorls (varix excluded)	10	11	**9**	9	10	8	9	10	10	9	10	9	9	11	12	8-12	9.733	1.033
N° spiral cords on last whorls	11	11	**11**	9	11	10	10	9	11	10	9	10	10	9	10	9-11	10.066	0.884
N° spiral cords on the base (excluding sutural cord)	5	5	**5**	3	5	4	4	3	5	4	3	4	4	3	4	3-5	4.066	0.737
N° number of denticles inside the aperture	8	no	**no**	7	8	8	no	8	no	no	7	7	no	no	8	no/7-8	7.625	0.518
Protoconch	1	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	Min-max	Mean	Std
Height	0.350	0.375	**0.350**	0.400	0.400	0.375	0.375	0.350	0.375	0.375	0.325	0.350	0.350	0.350	0.337	0.325-0.400	0.362	0.022
Diameter of nucleus	0.125	0.125	**0.150**	0.150	0.150	0.150	0.137	0.150	0.137	0.150	0.125	0.125	0.137	0.150	0.137	0.125-0.150	0.140	0.011
Diameter of first half whorl	0.250	0.250	**0.250**	0.275	0.275	0.250	0.250	0.262	0.250	0.275	0.225	0.250	0.250	0.275	0.250	0.225-0.275	0.256	0.014
Maximum diameter	0.400	0.425	**0.400**	0.400	0.412	0.425	0.400	0.425	0.400	0.412	0.400	0.425	0.400	0.425	0.387	0.387-0.425	0.409	0.013
N° of whorls	1.3	1.3	**1.3**	1.4	1.4	1.4	1.35	1.3	1.4	1.25	1.25	1.25	1.5	1.25	1.5	1.25-1.5	1.343	0.086

Table 1. Measurements of teleoconch and protoconch of *Alvania rominae* n. sp. in mm, with range, mean and standard deviation. 1 = S. Isidoro 53 m depth (SEM); 2 = Otranto 35 m depth (SEM); 3 = holotype, Gallipoli 58 m depth (SEM); 4 = Gallipoli -58 m; 5 = Gallipoli 58 m depth; 6 = Gallipoli 58 m depth; 7 = Gallipoli 58 m depth; 8 = Otranto 35 m depth; 9 = Otranto 35 m depth; 10 = Otranto 35 m depth; 11= P. Cesareo 40 m depth; 12= P. Cesareo 40 m depth; 13 = S. Isidoro 53 m depth; 14 = S. Isidoro -53 m; 15 = S. Isidoro 53 m depth.

Otranto illustrated by Scuderi & Terlizzi (2012), and indicated as conspecifics with the specimens of the Tremiti Islands figured by Micali et al. (2005), are not this species and are rather to be referred to one of the morphs of *A. lineata* (see e.g. the 4 spiral cords above the aperture vs 5 in *A. rominae* n. sp.).

A. rominae n. sp. differs from *A. elisae* by its fewer and narrower axial ribs on the last whorl (8–12 vs 15–16 in *A. elisae*), the wider interspaces, the 5 spiral cords above the aperture vs 4 in *A. elisae*.

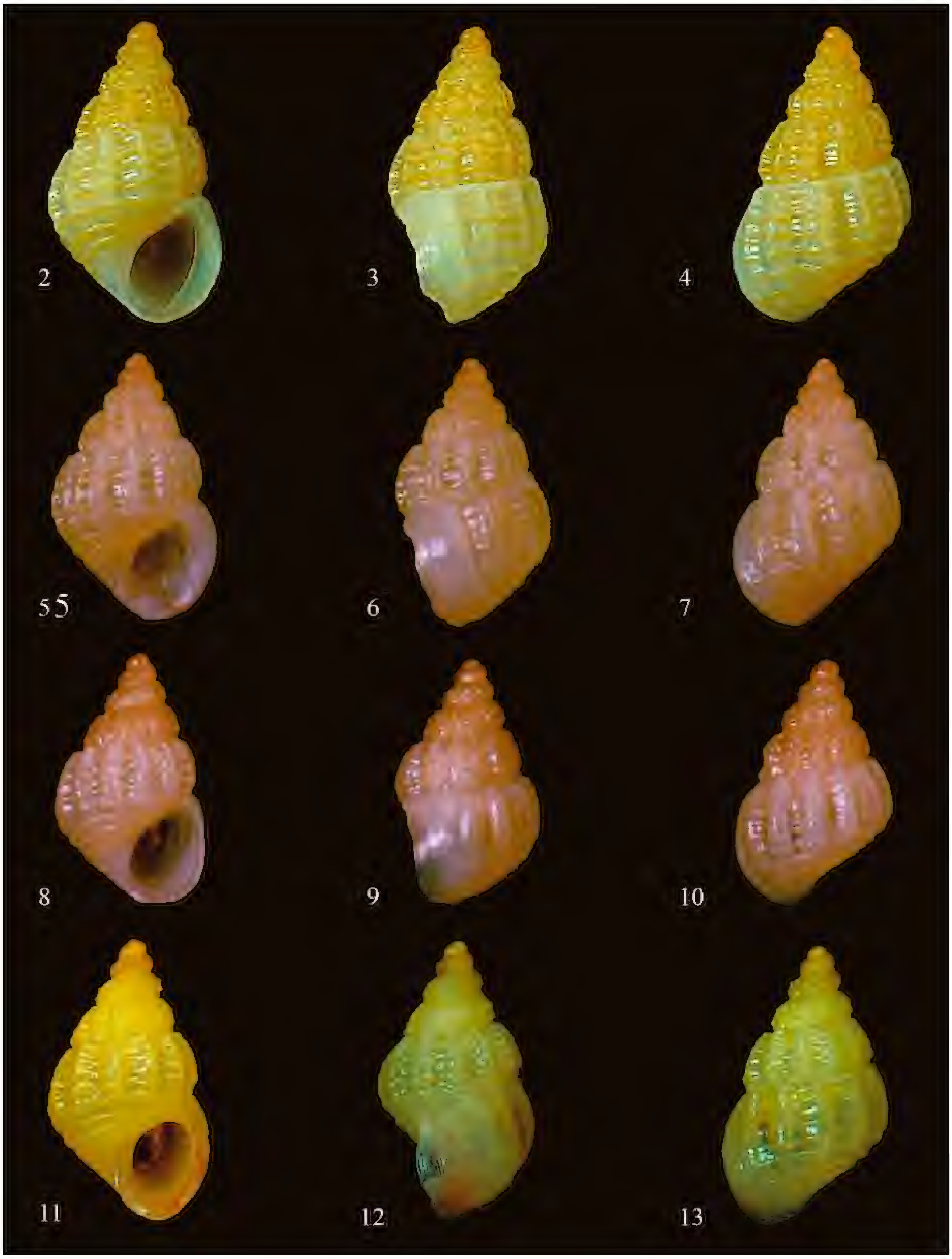
Alvania rominae n. sp. differs from *A. lineata* in its more obsolete spiral sculpture on the last whorl, the 5 spiral cords above the aperture (vs usually 4, rarely 5 in *A. lineata*), and for the axial ribs interrupted at the periphery: *A. lineata*, in its most common morphotypes, has a stronger sculpture, especially the spirals, with marked nodules at intersections, a thicker varix and the axial ribs reaching the base.

Alvania rominae n. sp. differs from *A. settepassii* in its variable chromatic pattern vs a rather constant one in *A. settepassii*, cream-orange to brown with darker axial interspaces; narrower axial ribs, the lack of a subsutural shoulder *vs* a scalariform outline with subsutural shoulder in *A. settepassii*.

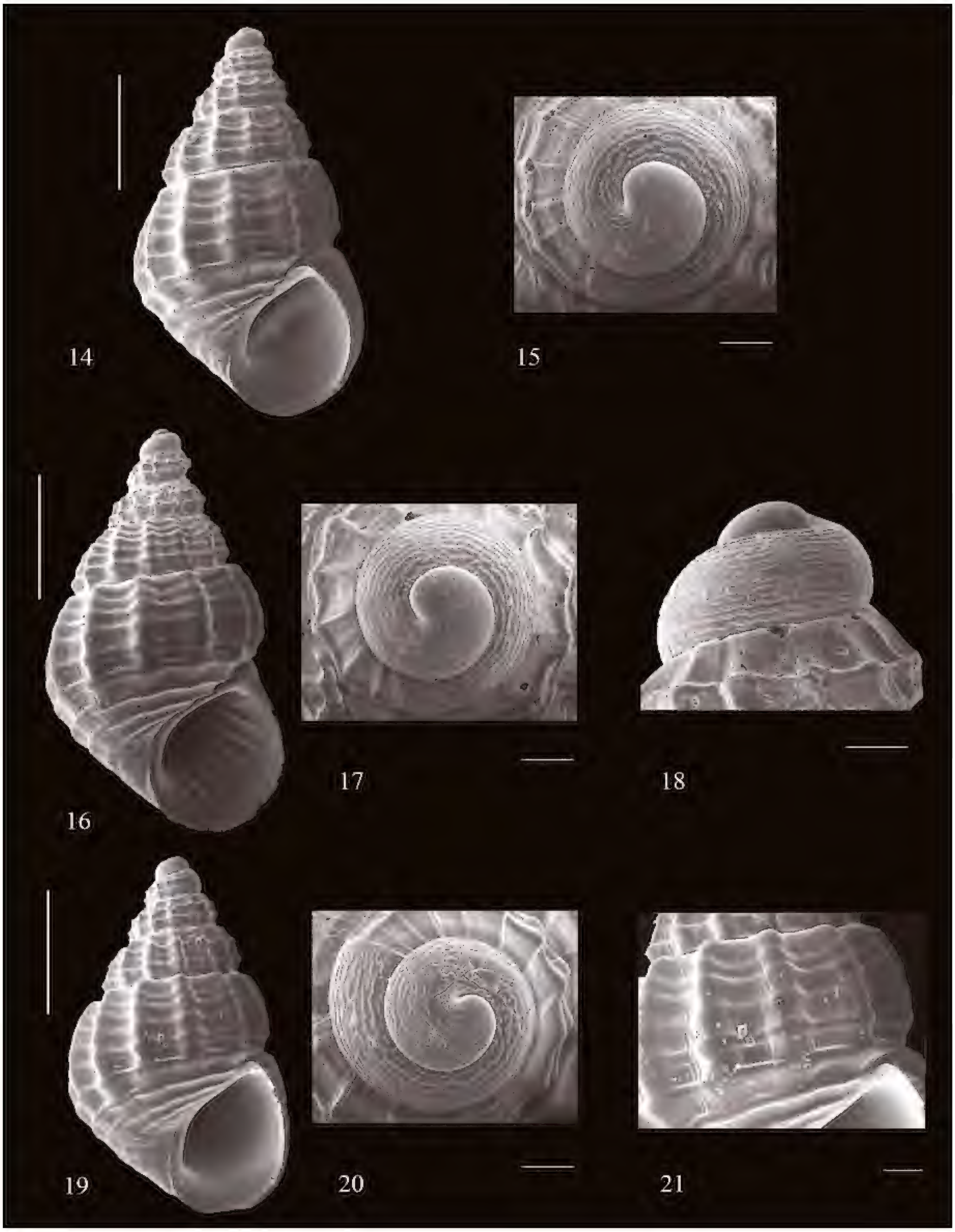
Alvania rominae n. sp. differs from *A. schwartziana* in its globose and more strongly sculptured protoconch, with a dozen slightly wavy spiral rows, partially anastomized vs a more acute protoconch with slightly convex whorls and with a more delicate sculpture (after comparison with four syntypes, from Zadar (Croatia), ex Brusina in the Monterosato collection MCZR-M-22326), its smaller protoconch (maximum diameter 0.387–0.425 mm vs 0.511 mm in *A. schwartziana*), the 5 spiral cords above the aperture vs 4 in *A. schwartziana*. Different chromatic pattern, monochrome brown in *A. schwartziana*.

Alvania rominae n. sp. differs from *A. bartolinorum* in its smaller protoconch (maximum diameter 0.387–0.425 mm vs 0.440–0.500 mm in *A. bartolinorum*), and its usually fewer axial ribs on the last whorl (8–12, mean 9.73 [N=15] vs 12–18, mean 14.25 [N=25] in *A. bartolinorum*). The number of spiral cords on the last whorl above the aperture are always 5 in *A. rominae* n. sp. vs 4–6 in *A. bartolinorum*. *Alvania rominae* n. sp. seems to be on average smaller: H. 2.90–3.60 mm (mean 3.228 mm) [N=15] vs H. 2.84–3.96 mm (mean 3.415 mm) [N=25] in *A. bartolinorum*.

Alvania rominae n. sp. differs from *A. zaraensis* in its protoconch, larger (maximum diameter 0.387–0.425 mm vs 0.325–0.375 mm in *A. zaraensis*), and with strong sculpture vs devoid of a strong sculpture in *A. zaraensis*, in the 5 spiral cords above the aperture vs 4 in *A. zaraensis*, the umbilical chink absent vs umbilical chink very narrow in *A. zaraensis*. Double sculpture (axial and spiral) much more robust with greater thickness.



Figures 2–13. *Alvania rominae* n. sp. Figs. 2–4: holotype, Gallipoli (Italy) 58 m depth, height 3.5 mm (MNHN-IM-2000–35744). Figs. 5–7: paratype, Gallipoli (Italy) 58 m depth, height 3.2 mm (DT). Figs. 8–10: paratype, Otranto (Italy) 35 m depth, height 2.9 mm (DT). Figs. 11–13: paratype, S. Isidoro (Italy) 53 m depth, height 3.25 mm (DT).



Figures 14–21. *Alvania rominae* n. sp. (SEM). Fig. 14-15. Holotype, Gallipoli (Italy) 58 m depth: shell (Fig. 14), detail of the protoconch microsculpture (MNHN-IM-2000-35744) (Fig. 15). Figs. 16–18. Paratype, S. Isidoro (Italy): shell (Fig. 16), detail of the protoconch microsculpture (DT) (Figs. 17, 18). Figs. 19–21. Paratype, Otranto (Italy): shell (Fig. 19), detail of the protoconch and teleoconch microsculpture respectively (DT) (Figs. 20, 21). Scale bars = 1 mm (14, 16 and 19), = 100 µm (15, 17, 18, 20), = 200 µm (21).

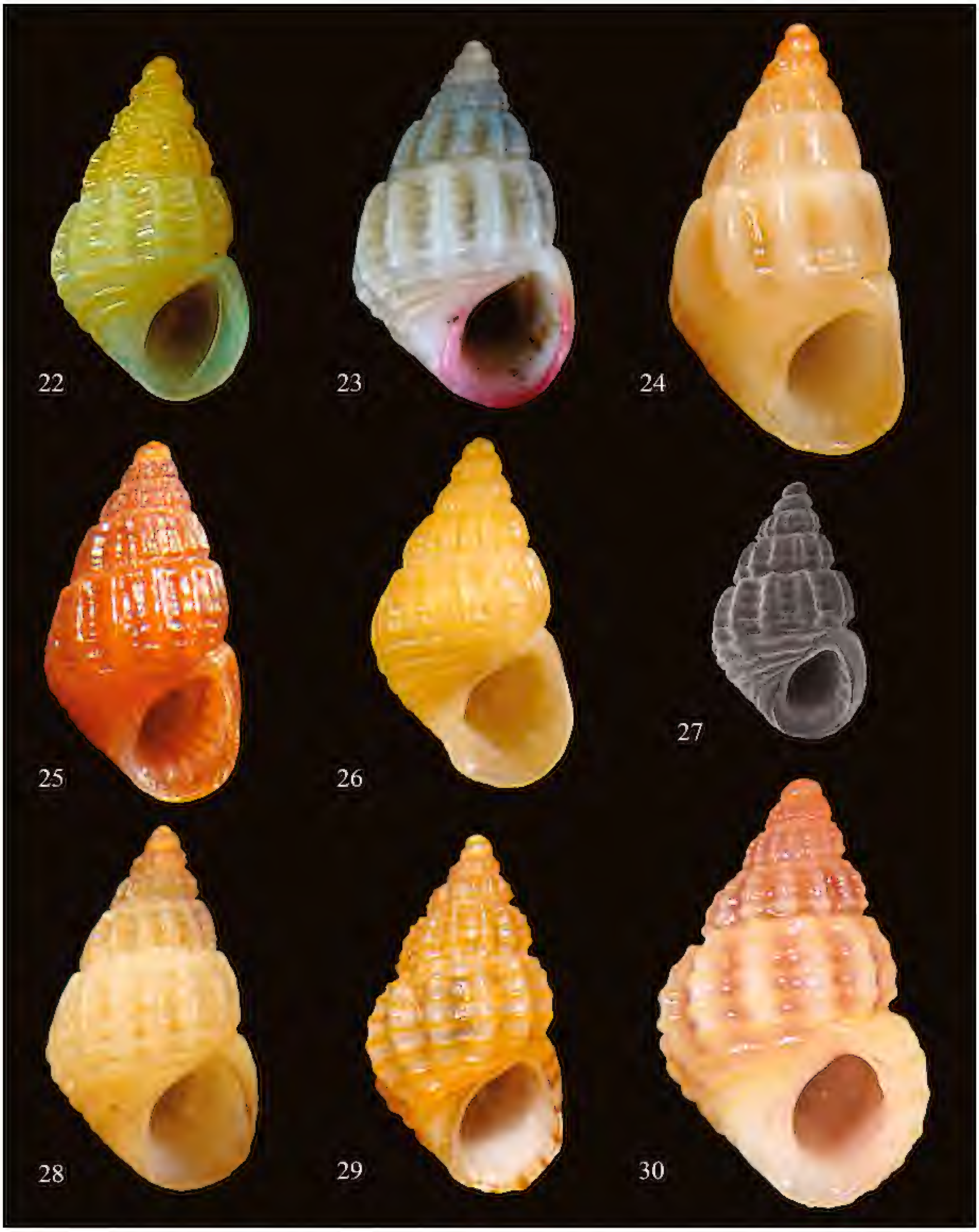
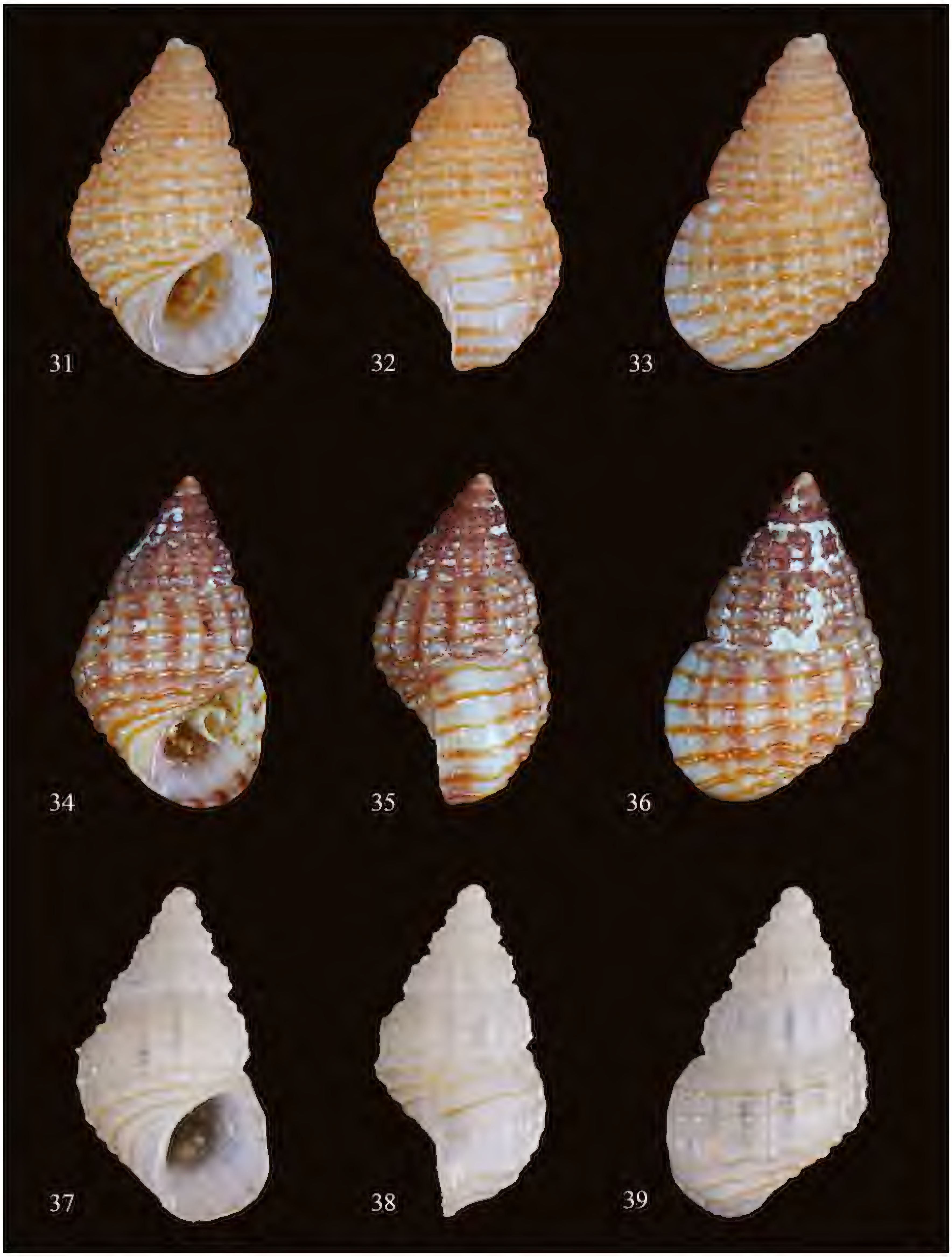
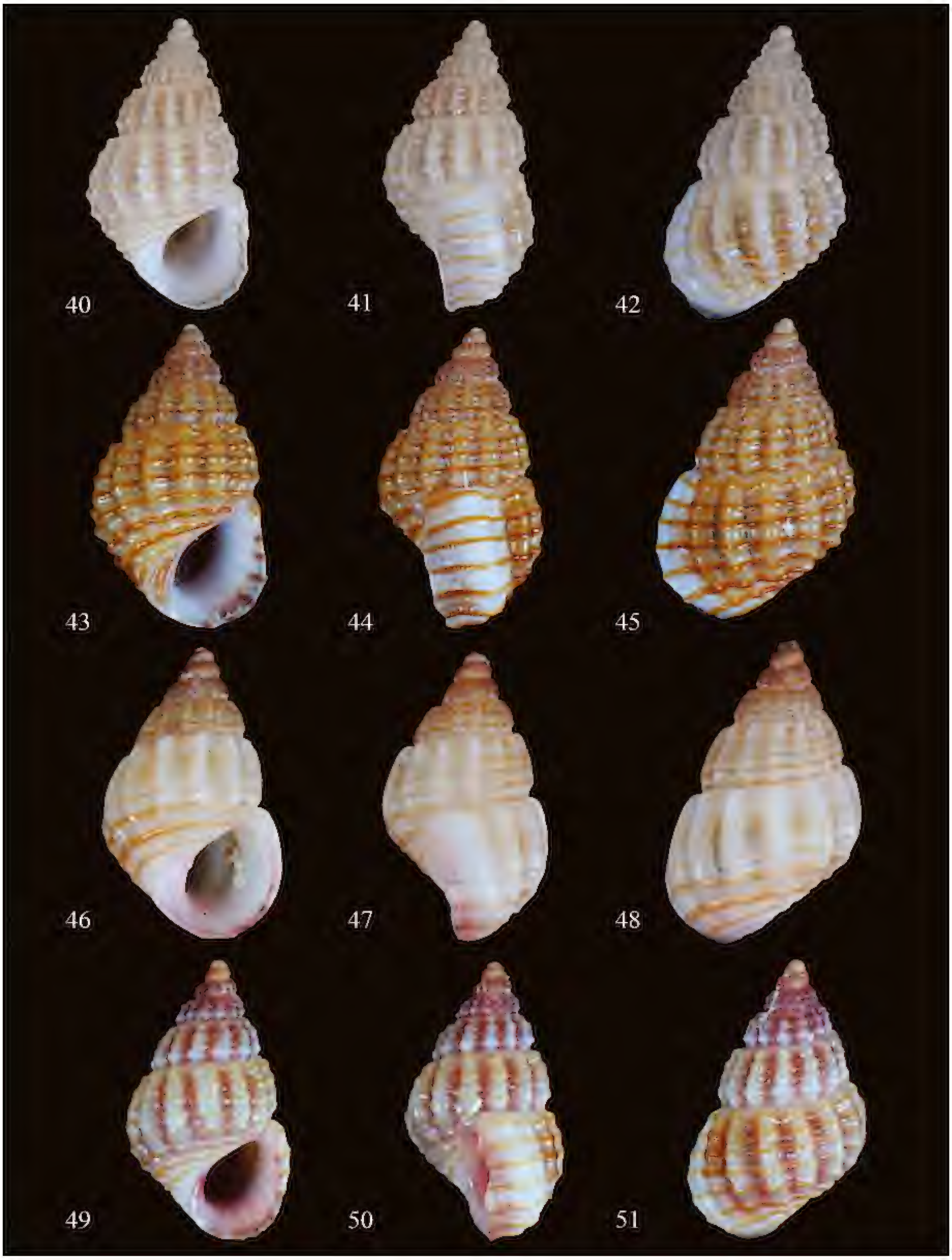


Figure 22. *Alvania rominae* n. sp. holotype, Gallipoli (Italy) 58 m depth, height 3.5 mm (MNHN-IM-2000-35744). Figure 23. *Alvania settepassii*, Porto Cesareo (Italy) 30 m depth, height 3.7 mm (DT). Figure 24. *Alvania settepassii*, paratype, Torrevaldaliga, Civitavecchia (Italy) 25–30 m depth, height 4.3 mm (BA). Figure 25. *Alvania schwartziana*, Pag (Croatia), height 3.6 mm (BA). Figure 26. *Alvania bartolinorum*, holotype, Krk Island (Croatia) 54 m depth, height 3.58 mm (MNHN-IM-2000-27706). Figure 27. *Alvania zaraensis*, holotype, Zadar (Croatia), height 2.6 mm (MCZR-M-22152/H). Figure 28. *Alvania elisae*, paratype, Capraia Island (Italy) 2–15 m depth, height 3.75 mm (CS-PM). Figure 29. *Alvania lineata*, Salina Island (Sicily) 35 m depth, height 3.65 mm (BA). Figure 30. *Alvania lineata*, Cala Gonone, Dorgali (Sardinia) 1 m depth, height 4.3 mm (BA).



Figures 31–39. *Alvania lineata* Risso, 1826. Figs. 31–33: Gallipoli (Italy) 2.5 m depth, height 3.63 mm (DT). Figs. 34–36: Castro (Italy) 23 m depth, height 4.32 mm (DT). Figs. 37–39: Nardò, loc. S. Caterina (Italy) 23 m depth, height 3.15 mm (DT).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Figures 40–51. *Alvania lineata* Risso, 1826. Nardò (Lecce), località Torre Inserraglio (Italy) 23 m depth. Figs. 40–42: height 4.39 mm (DT). Figs. 43–45: height 4.23 mm (DT). Figs. 46–48: height 3.84 mm (DT). Figs. 49–51: height 3.91 mm (DT).

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Description of seven new species of seed beetles (Coleoptera Bruchidae) from Mediterranean basin and Africa

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ABSTRACT In this work, seven species of Bruchidae new to science are described. Five of these species belonging to the genus *Bruchidius*, namely *Bruchidius horshensis* n. sp., *Bruchidius lekefensis* n. sp., *Bruchidius salinaensis* n. sp., *Bruchidius bcharreensis* n. sp., *Bruchidius samai* n. sp. are from Mediterranean area. The remaining two new taxa, namely *Spermophagus nicotrai* = *Spermophagus* sp. Zampetti, 1988 and *Protobruchus* (n. gen.) *togoensis* n. sp., are respectively from East Africa and from West Africa. Figures of the specimens and of respective genitalia are provided.

KEY WORDS Taxonomy; seed weevils; Bruchidae; *Bruchidius*; *Spermophagus*; *Protobruchus*.

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INTRODUCTION

The family Bruchidae Latreille, 1802 (Coleoptera) consists of about 1700 described species belonging to 60 genera and ranged in the subfamilies Amblycerinae, Bruchinae, Eubaptinae, Kytorhininae, Pachymerinae, and Rhaebinae (Southgate, 1979; Johnson & Kingsolver, 1981). In this study, the Authors choose to keep the name of this group as a family according to Yus Ramos et al. (2007), despite the subsequent proposals introduced by Bouchard et al. (2011), in which Bruchidae have been formally downgraded to a subfamily within Chrysomelidae. This family occurs in the whole world but the poles and the deserts. Even if the majority of the species is limited to their natural ranges of distribution, a few of them became cosmopolitan because of the passive dispersion by human activities. In fact, also known as seed beetles, Bruchids feed on seeds of various plant families, but mainly the Fabaceae (= Leguminosae); several species became pests of legumes used as a food source for both people and livestock. In recent years, we have witnessed a significant proliferation of species that develop on ornamental plants in different parts of the world including Europe. In general, seed trade caused, and causes nowadays, the incoming of these species into Europe from other countries. Among many species passively imported, some of them become invasive establishing in natural habitats and integrating in European ecosystems, especially in the Mediterranean area (Yus-Ramos et al, 2014). In this work seven new species of Bruchidae from the Mediterranean area and Africa are described on the base on unique specimens evidently different from any other species known today. Five of these species belonging to the genus *Bruchidius* Schilsky, 1905, one to the genus *Spermophagus* Schoenherr, 1833 and one to the new genus *Protobruchus* are here described. *Bruchidius horshensis* n. sp., *Bruchidius lekefensis* n. sp., *Bruchidius salinaensis* n. sp., *Bruchidius* *bcharréensis* n. sp., and *Bruchidius samai* n. sp. are from the Mediterranean area, *Spermophagus nicotrai* = *Spermophagus* sp. Zampetti 1988 is from East Africa and *Protobruchus togoensis* n. sp. is from West Africa. The descriptions have been carried out on unique specimens.

MATERIAL AND METHODS

Measurements of the specimens were taken as reported in Zampetti & Ricci (2012). Dry genitalia were left in KOH 10-15% solution for 1 hour then cleaned in pure water and finally mounted on microscope slides in polyvinyl alcohol by the first author, according to Zampetti & Ricci (2012).

Figures of the specimens and of respective genitalia are provided and have been taken from slide preparations. No data on distribution and host plants are available about these species as specimens were occasionally collected. Due to their Southern Mediterranean origin, of these specimens have been described on the base of what is reported in the references on the species from northern Africa, the Middle East and exotic seed beetles in general (Allard, 1868, Migliaccio & Zampetti, 1989; Pic, 1902, 1903, 1904, 1913a, 1913b, 1913c; Ricci & Zampetti, 2005, 2007). The description of the species through the type's examination is reported below.

The holotypes and paratypes of the new species here described are deposited at the National History Museum of London (UK) within the Zampetti collection.

RESULTS

Systematics

Ordo COLEOPTERA Linnaeus, 1758
Subordo POLYPHAGA Emery, 1886
Superfamilia CHRYSOMELOIDEA Latreille, 1802
Familia BRUCHIDAE Latreille, 1802
Genus *Bruchidius* Schilsky, 1905

Bruchidius horshensis n. sp. - Figs. 1–3
http://zoobank.org/4fa2f599-a1be-4ea9-8df1-66174dc832bc

EXAMINED MATERIAL. Types examined. Female holotype. Liban, Zgharta, Horsh Ehden, Nat. Res., 1700 m above s.l., 8/16.VI.1999, G. Sama legit; 2 female paratypes, same data of the holotype.

DESCRIPTION OF THE HOLOTYPE. Female, habitus as in figures 1 and 2. Length: 5.7 mm, width 2.5mm. Body elongated and oval, and completely black. Oval body extremely elongated with greater width and main convexity just before the middle part of the body at about 1/3 from the base of elytra. The insect is black with the exception of the second antennal segment which is dark red. It is covered by an ashy- grey uniform pubescence over the whole body but a long tuft of light gray bristles is present across the middle part and at the sides of the pygidium.

The head has the clypeus a quarter longer than wide, the forehead-clypeus edge is present but not very engraved, the frontal carena is complete, evident and translucent with no narrowing behind the eyes. The markings are deep and the pubescence is thin of ashy color, denser on the clypeus and on its sides. The antennae go just over the base of the elytra and are serrated starting from the fifth article. Article 2 is sub-triangular as long as it is wide, the 3rd is almost cylindrical, about 1.5 times longer than wide and longer than the 2nd but of equal width. The 4th antennal segment is slightly longer and a little wider than the previous one; the 5th is a little longer and wider than the 4th, about 1.5 times the width. The antennal items from the 5th to the 10th are sub-triangular decreasing in length but of constant width so that the 10th results having the same width and length.

The prothorax has a conic shape with straight back angles, just longer than wide, uniformly convex although there are two evident depressed areas, one to every side of the basal lobe. It presents slightly sinuous sides, and the base is also straight with a protruding central part. The basal edge is absent while the apical one is present but incomplete in the upper part. The pubescence is light and uniform with a tuft of bristles in the middle of the base; the markings are uniform and coarse. The scutellum is small and has a semi-triangular shape, as wide as long, covered by a light, ashy-white and uniform pubescence presenting markings that are similar to the prothorax.

The elytra are rectangular, roughly 1.5 times longer than wide, slightly convex, and there are no tubercles at the base. The markings are thin and light thus not appearing very visible whilst the pubescence is so thick that it tends to hide the underlying tegument, especially in the apical part whilst appearing thinner on the humeri.

The legs present a strong and clearly visible tooth on the inner part of the back femurs. The tibias are straight, with the back ones ending with two short black thorns one longer than the other. The total length of the back tarsi is slightly inferior to the length of the respective tibiae.

The pygidium is flat, with the exception of a longitudinal central convexity from the base to the apex, slightly tilted in comparison to the surface, about 2 times longer than wide at the base presenting no curving at the apex. The markings are very fine and shallow thus presenting a somewhat wrinkled appearance on the surface. The greyish pubescence is rather uniform but thicker in the center of the basal part, on the sides and along the central convexity. Female genital typical of the genus *Bruchidius* (Fig. 3).

VARIABILITY. Female paratypes do not have substantial morphological differences with the described holotype. Male: unknown.

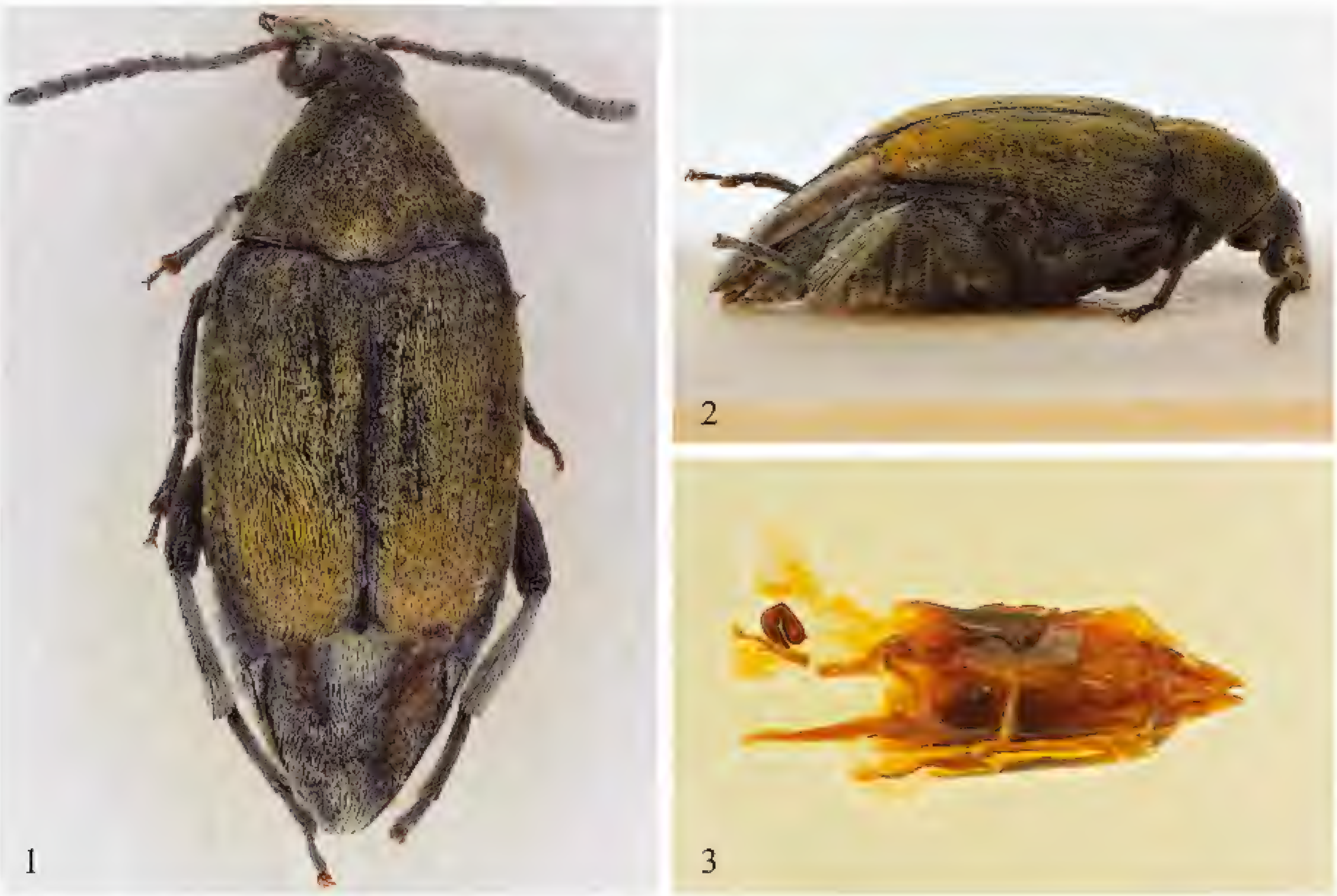
DISTRIBUTION. This new species is known only from the locus typicus: Liban, Zgharta, Horsh Ehden Natural Reserve, 1700 m above s.l., 8/16.VI.99. G. Sama leg.

DIFFERENTIAL DIAGNOSIS. The filiform antennae, the elongated body shape and in particular the pygidium together with the tomentosity of the elytra are characters in common with *Bruchidius cinerascens* (Gyllenhal, 1833) and to the *Bruchidius monstrosicornis* (Pic, 1904).

Bruchidius lekefensis n. sp. - Figs. 4–6
http://zoobank.org/6830cde4-de76-465b-83d9-975e3f67a77e

EXAMINED MATERIAL. Holotype male. Tunisia, km 25 Le Kef-Teboursouk road, 400–500 m above s.l., S. Zoia legit, 18.IV.1993.

DESCRIPTION OF THE HOLOTYPE. Male's habitus as shown in figures 4 and 5. Lenght: 3.8 mm, maximum width: 1.8 mm. Short and oval body. Completely



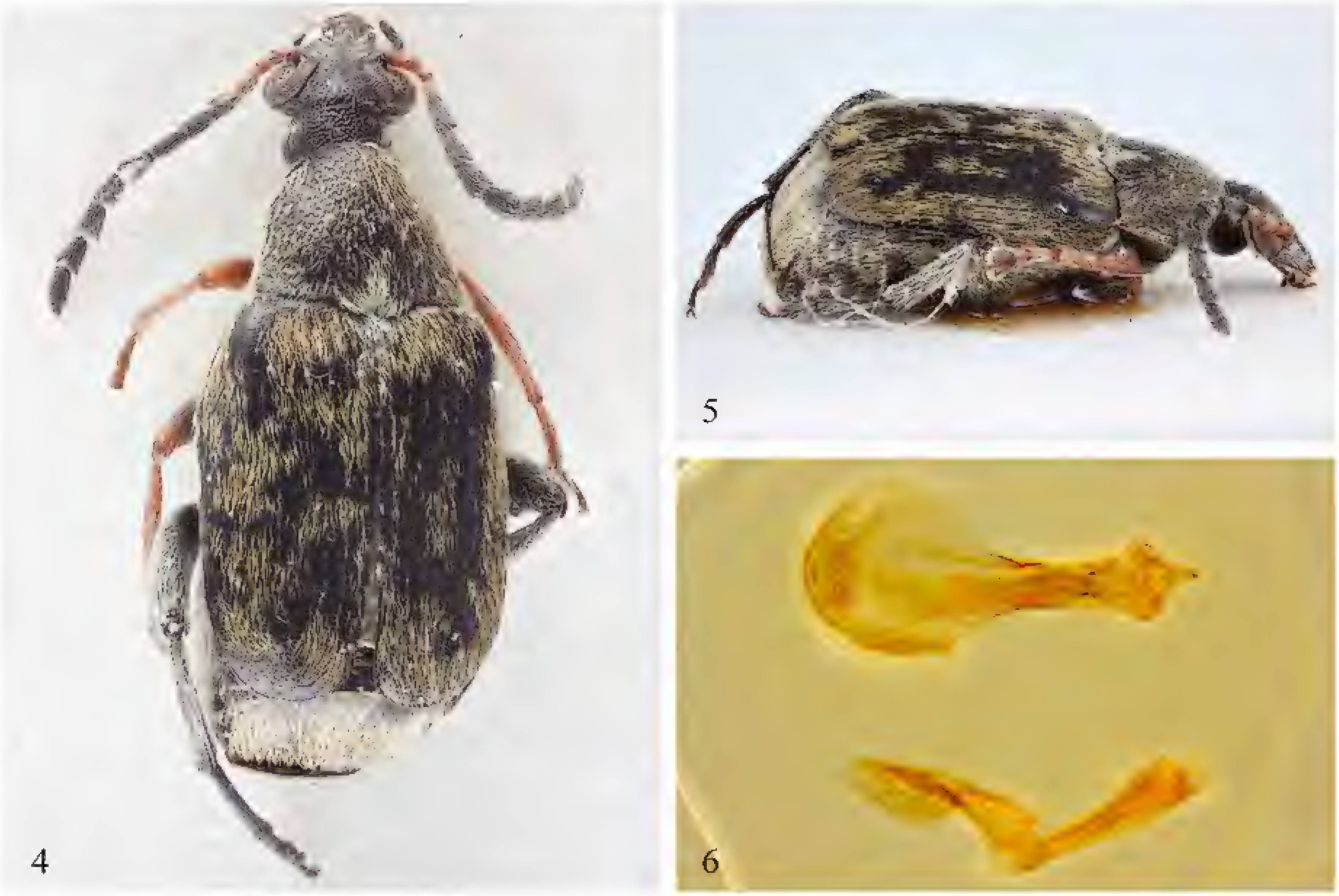
Figures 1–3. *Bruchidius horshensis*. Fig. 1: habitus of the type female, dorsal view. Fig. 2: habitus of the type female, lateral view. Fig. 3: genitalia of the female.

black body. Oval body, elongated meaning wider in the middle and the maximum convexity from 1/3 from the base of the elytra. Species of black color with the exception of the articles 1-3 of the antennae and the legs partially red. It is covered by a very light ashy-grey pubescence almost uniform over the whole body with the exception of the pygidium which is denser thus hiding the underlying tegument.

The head with the clypeus slightly longer than wider with the line of the forehead-clypeus forming a distinctive V shape. The frontal carena is complete and shiny, well evident. No narrowing behind the eyes. The markings are deep and coarse, with a thin ashy-gray pubescence. The antennae go beyond the base of the elytra but are shorter than half of the body; they are serrated starting from the 4th article. The 2nd article is spherical in shape having the same length and width; the 3rd item is triangular about 1.5 longer than wider, and 1.5 times longer than the 2nd. The 4th article is roughly 1/3 longer and wider than the previous. The articles from the 5th to the 10th have a sub-triangular shape constant in length and width, 1.5 times longer than wider.

Conic prothorax with sharp back angles, 1.3 times wider than longer and uniformly convex, with two sunken areas in front of the back angles. It portrays sinuous edges, the base is straight with a slightly protruding central part. The apical edge is complete and distinct whilst the basal part is just outlined. The pubescence is thin, uniform and of ashy-gray color, with a lock of bristles in front of the scutellum. The markings are uniform and deep, as on the head. The scutellum has the same measurements in length and width and is covered by a dense ash-white uniform pubescence.

Rectangular elytra, with almost parallel sides, about 1.5 times longer than wider, almost convex. There are no tubercles at the base. The markings are uniform and clear composed of small dots and the pubescence is uniform and thin. The humeri have no hair. First and second legs are of a red brown color but the femurs are darkened at the basal part. Back femurs have a dwarfish tooth, just



Figures 4–6. *Bruchidius lekefensis*. Fig. 4: habitus of the type male, dorsal view. Fig. 5: habitus of the type male, lateral view. Fig. 6: aedeagus.

visible, on the inner side. The tibiae are straight, the back ones ending with some black thorns of the same length.

The pygidium is very reclined, almost perpendicular, slightly longer than wider; rather convex with a curved apex. The pubescence and the markings are both fine, dense and uniform.

The aedeagus shows cylindrical median lobe with linear and parallel sides. The apex is widened terminating with a small but well visible thorn. The paramers have a linear aspect expanding in width. The lobes are turned toward the inside having bristles in the apical part. The basal part holds the paramers together and it is composed by two segments fused around the median lobe that are extended with an odd piece (Fig. 6).

VARIABILITY. Female unknown.

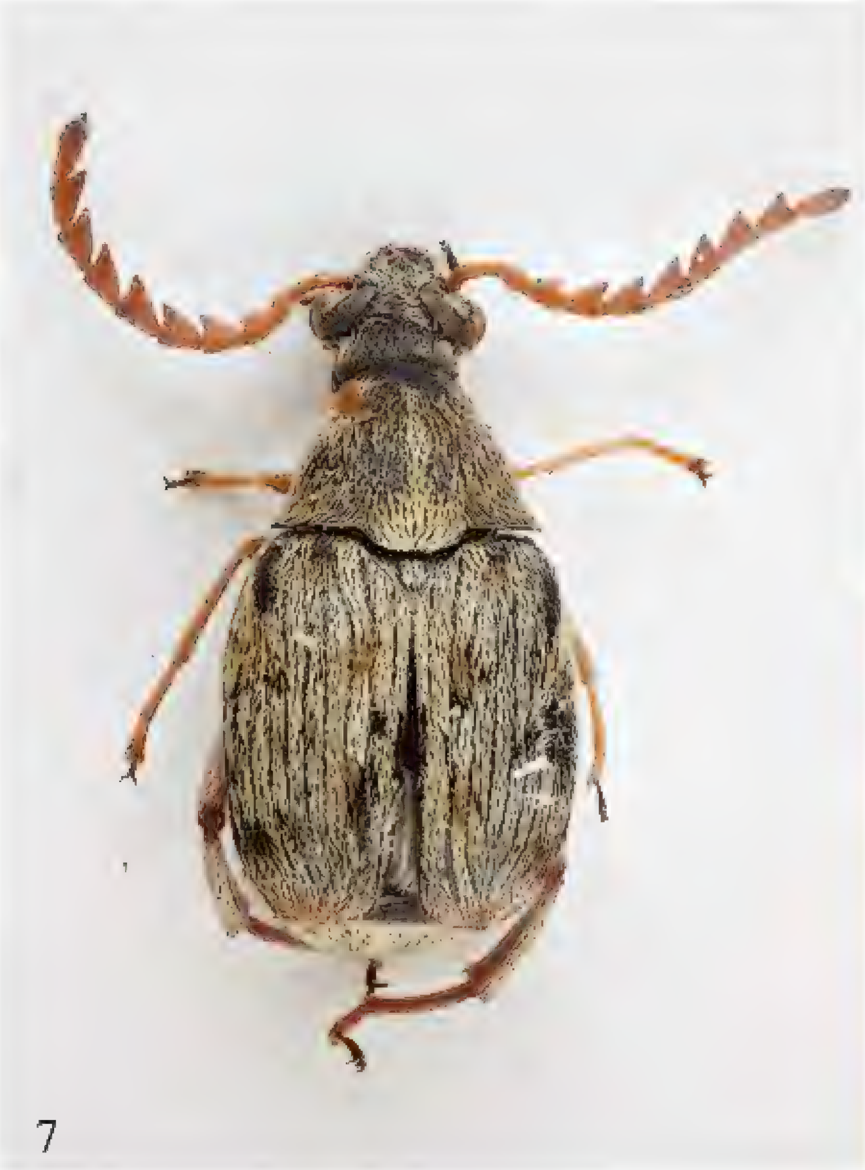
DISTRIBUTION. This new species is known only from the locus typicus: Tunisia, km 25 Le Kef-Teboursouk road.

DIFFERENTIAL DIAGNOSIS. although it presents flat elytrae, this bruchid appear very close to *Bruchidius varipictus* (Motschulsky, 1873).

Bruchidius salinaensis n. sp. - Figs. 7–9
http://zoobank.org/664d6b61-77fa-4bbc-8f17-759e98403d06

EXAMINED MATERIAL. Holotype male. Salina, Lingua, Sicily, Italy, P. Lo Cascio & F. Grita legit, 10.V.2009.

DESCRIPTION OF THE HOLOTYPE. Male, habitus as in figures 7 and 8. Length: 3.5 mm; width: 1.7 mm; the shape of the body is short and oval, totally black in color. Oval elongated body with the maximum width beyond the middle of the body and the maximum convexity at 1/3 from the base of the elytra. The insect is black with the exception of the antennae and the legs which are dark red. It is covered by an ashy-gray uniform pubescence on the whole body but two locks of light brown bristles are noticed on the third gap of each elytra, one in front and the other one behind its middle. The head with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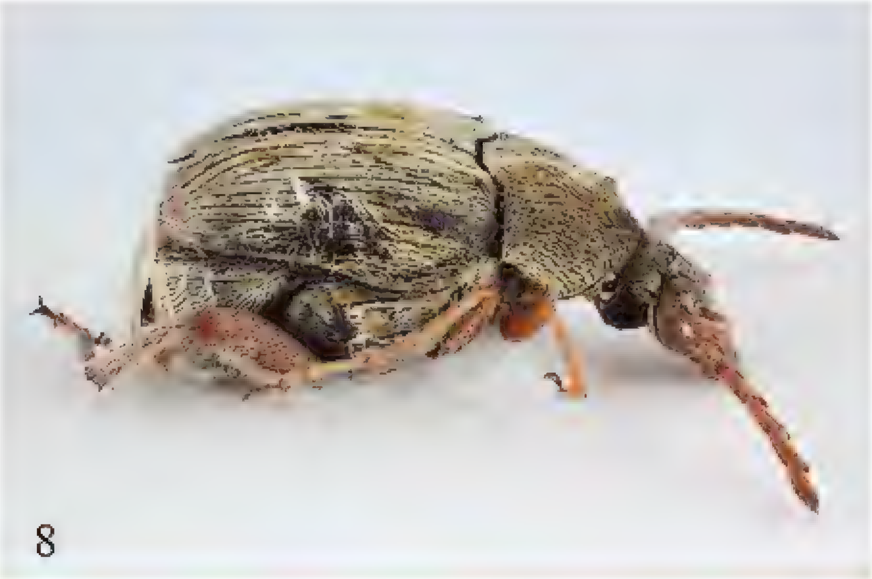
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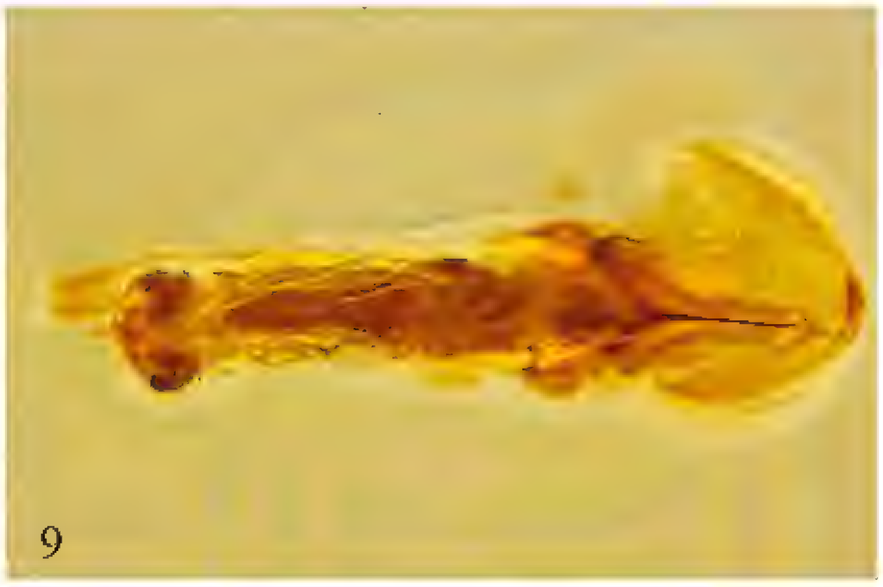
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Figures 7–9. *Bruchidius salinaensis*. Fig. 7: habitus of the type male, dorsal view. Fig. 8: habitus of the type male, lateral view. Fig. 9: aedeagus.

the clypeus slightly longer than wider, forehead-clypeus edge present but hard to see, frontal carena complete, very clear with no narrowing behind the eyes. The markings are deep and the pubescence is sparse and is ashy-gray.

The antennae exceed the base of the elytra and are serrated starting from the fourth article. The 2nd article is of spherical shape having the same measurements in length and in width; the 3rd is triangular but the upper side is not perpendicular to the axis but tilted toward the outside; it is a little longer than wider about twice the length of the 2nd. The 4th segment is slightly longer and wider than the previous. Antennal segments from the 5th to the 10th are subtriangular and constant in length. The width from the 5th to the 7th antennal segments expands while the 8th to the 10th decreases.

The prothorax is of conic shape with pointed back angles, 1.3 times wider than longer resulting uniformly convex although there are some hollowed areas in the middle and at the sides of the basal lobe. It portrays sinuous sides, the base is straight with a very protruding central part. The basal and the apical edges are complete and distinct. The pubescence is dense and varied, more visible and off-white at the base and along a central longitudinal line. The markings are uniform and less pronounced than those on the head. The scutellum is the same in width and length, covered by a thick ashy-white uniform pubescence.

The elytra is square shaped, slightly longer than wider, and just a little convex. There are two tubercles at the base of the 3rd and 4th striae that are very close to each other giving the impression of being one tubercle. The markings are clear, composed of small dots and the pubescence is variegated, dense in some areas. A few dots of brown bristles on two transverse sections are visible, four on the anterior section at about 1/3 from the base and a further four dots on the posterior section at about 1/3 from the apex. The humeri have no hair. Legs have a small tooth on the inner part of the back femurs. The tibiae are straight, the back ones terminate with two short black thorns one longer than the other. The 1st segment of the tarsus of the first and second legs has no thorns. The pygidium is very tilted, virtually perpendicular to the surface, about 1.3 times longer than wider, a little convex and with a slightly curved apex. Both the pubescence and the markings are very thin and uniform.

Aedeagus: cylindrical median lobe with linear edges and the apex with two arc-shaped layers which, seen in section, form a heart shape. At the apex a small thorn is well visible: from the side, the median lobe appears curved in the sub-apical area due to the presence of the two arc-shaped layers. The paramers have linear edges and have the same width along the whole length. The lobes are turned towards the inside with bristles in the sub-apical part. From the side one can see an arc-shaped layer in the middle of the lobe of the paramers. The basal piece holds the paramers united and consists of two segments joined around the median lobe that continue with an odd-piece toward the apex. Spiculum gastrale with two segments forming a “V” shape and the third segment originating from their point of intersection and being just a little shorter (Fig. 9).

VARIABILITY. Female unknown.

DISTRIBUTION. This new species is known only from the locus typicus: Salina, Lingua, Aeolian Islands, Sicily, Italy.

DIFFERENTIAL DIAGNOSIS. This bruchid shows at the same time the elytra with tubercles at the base (a common character among black bruchids with scattered dense gray pubescence) and legs and elytrae red in color. These characters together with the 3rd antennal segment deformed triangle shaped, make this species very similar to *Bruchidius martinezi* (Alard, 1868).

Bruchidius bcharreensis n. sp. - Figs. 10, 11
http://zoobank.org/44b94540-f865-49bd-8bc0-85f7f68a1e90

EXAMINED MATERIAL. Holotype female. Liban, caza Bcharré, Cédres de Bcharré, 1950 m above s.l., P. Brignoli legit, 3/5.VI.1972.

DESCRIPTION OF THE HOLOTYPE. Habitus of the female as in figures 10 and 11. Length 2.5 mm, maximum width 1.3 mm; it has an oval shape, slightly elongated, with a completely black body apart from the legs and the antennae that are partially red. The female body is slightly elongated portraying the maximum width being behind the half-way part of the body in the middle of the elytra. This insect is black with some exceptions described here as follows. The first antennal segment is red becoming darker red in the upper part; the segments 2–4 are red as well as the legs even if in the third pair the femurs are darker red in the basal part. Tarsi are also brownish red. The body is covered by an ashy-grey uniform pubescence over the whole body apart from a lock of light grey bristles at the base of the thorax. The head with the clypeus has roughly the same width and length, the forehead-clypeus edge is present but only lightly engraved, the frontal carena is complete, evident, translucent and has no narrowing behind the eyes. The markings are not very deep and the pubescence is almost absent apart from the area between the eyes where it is very sparse and denser on the clypeus and on its lateral sides, it is an ashy color. The antennae begin from the base of the elytra and are serrated starting from the fifth segment. The 2nd segment is square shaped as long as wide; the 3rd segment is cylindrical and is fairly longer than the 2nd segment but has the same width. The 4th segment is almost double the length and wider than the previous and the 5th segment is a little longer than the 4th, as long as is wide. The antennal segments from the 6th to the 10th are subtriangular shaped and constant in length and in width, so that the 10th segment appears as long as it is wide.

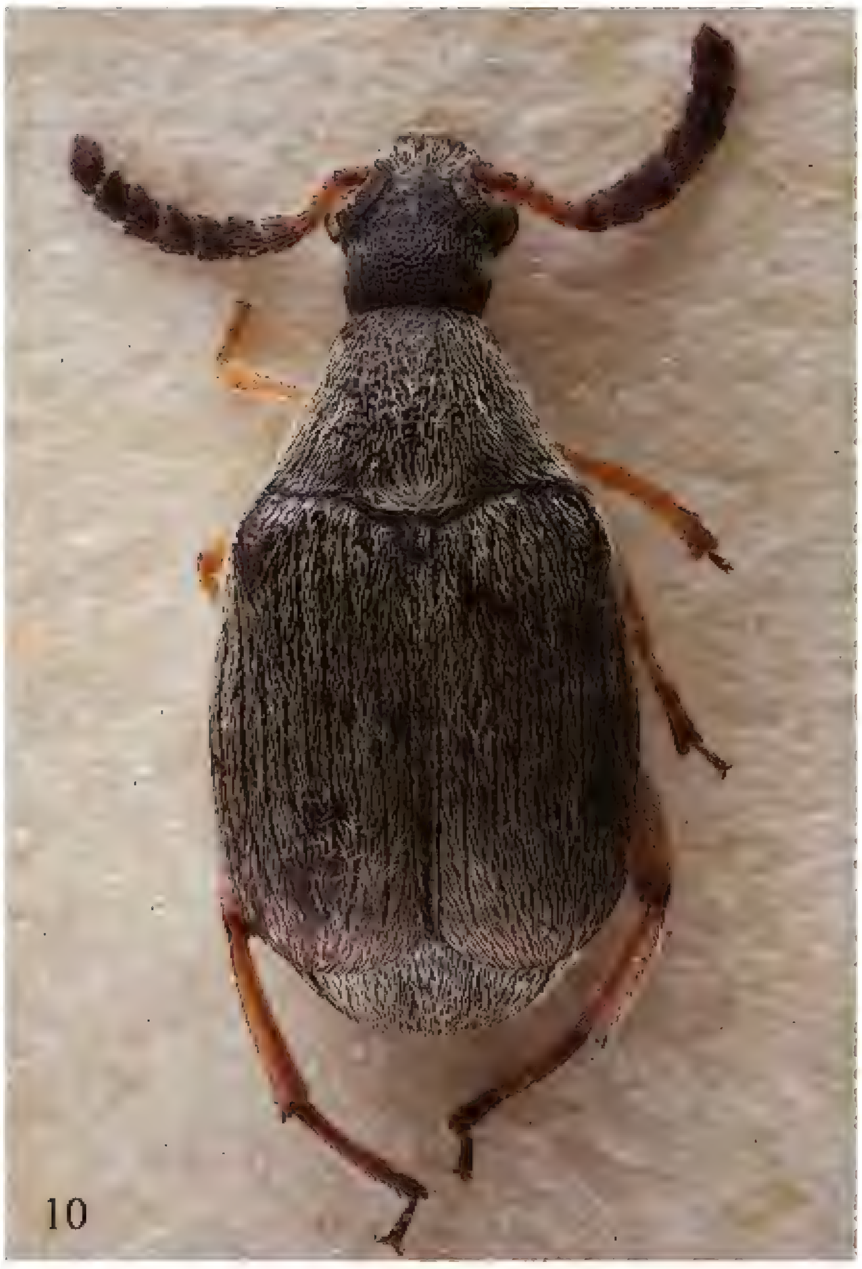
The prothorax is conical with straight back angles, slightly wider that longer, uniformly convex. It presents slightly sinuous sides, the base is also straight with the central part just a little protruding. The basal edge, as in its apical part as well as in its basal part, is complete. The pubescence is light and smooth with a large lock of bristles in the middle of the base; the markings are uniform and coarse. The scutellum is small, square shaped, as wide as long, covered by a light ashy-white pubescence and with markings that are similar to the ones on the prothorax.

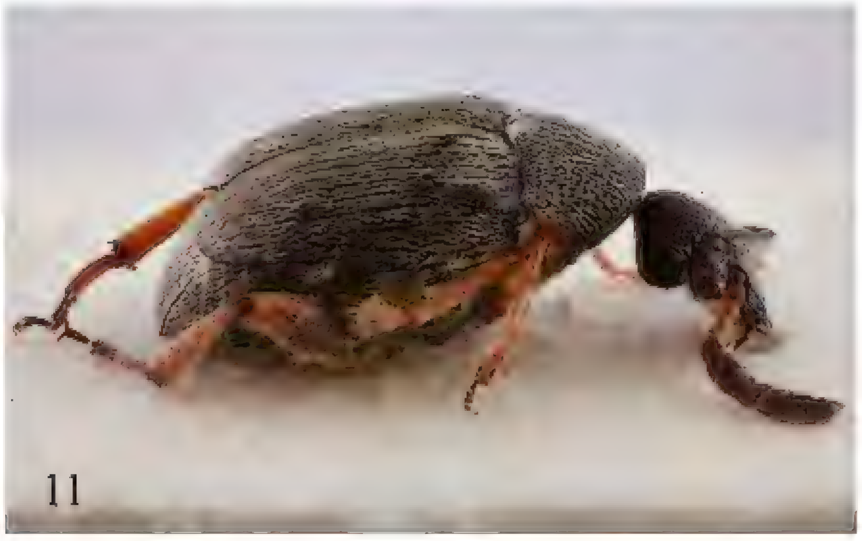
The elytra are rectangular, about 1.3 times longer than wider, and a little convex. One tubercle is present at the base of the fourth striae. The markings are sparse and light thus, not very visible, and the pubescence is so dense that it tends to hide the underlying tegument with the exception of the humeri where it is a little sparser. The legs have no tooth on the inside side of the rear femurs. The tibiae are straight, with the back ones ending with two short black thorns one longer and stronger than the other. The total length of the back tarsi is the same length of the respective tibiae.

The pygidium is slightly convex, uniform from the base to the top, very tilted compared to the surface, as long as wide. The markings are very fine and not very pronounced. The greyish pubescence is uniform, denser than the rest of the body similar to the one located at the base of the thorax. Female genital typical of the genus *Bruchidius*.

VARIABILITY. Male unknown.

DISTRIBUTION. This new species is known only from the locus typicus: Liban, caza Bcharré, Cédres de Bcharré, m 1950, - 3/5.VI.72. P. Brignoli leg.





Figures 10, 11. *Bruchidius bcharreensis*. Fig. 10: habitus of the type female, dorsal view. Fig. 11: habitus of the type female, lateral view.

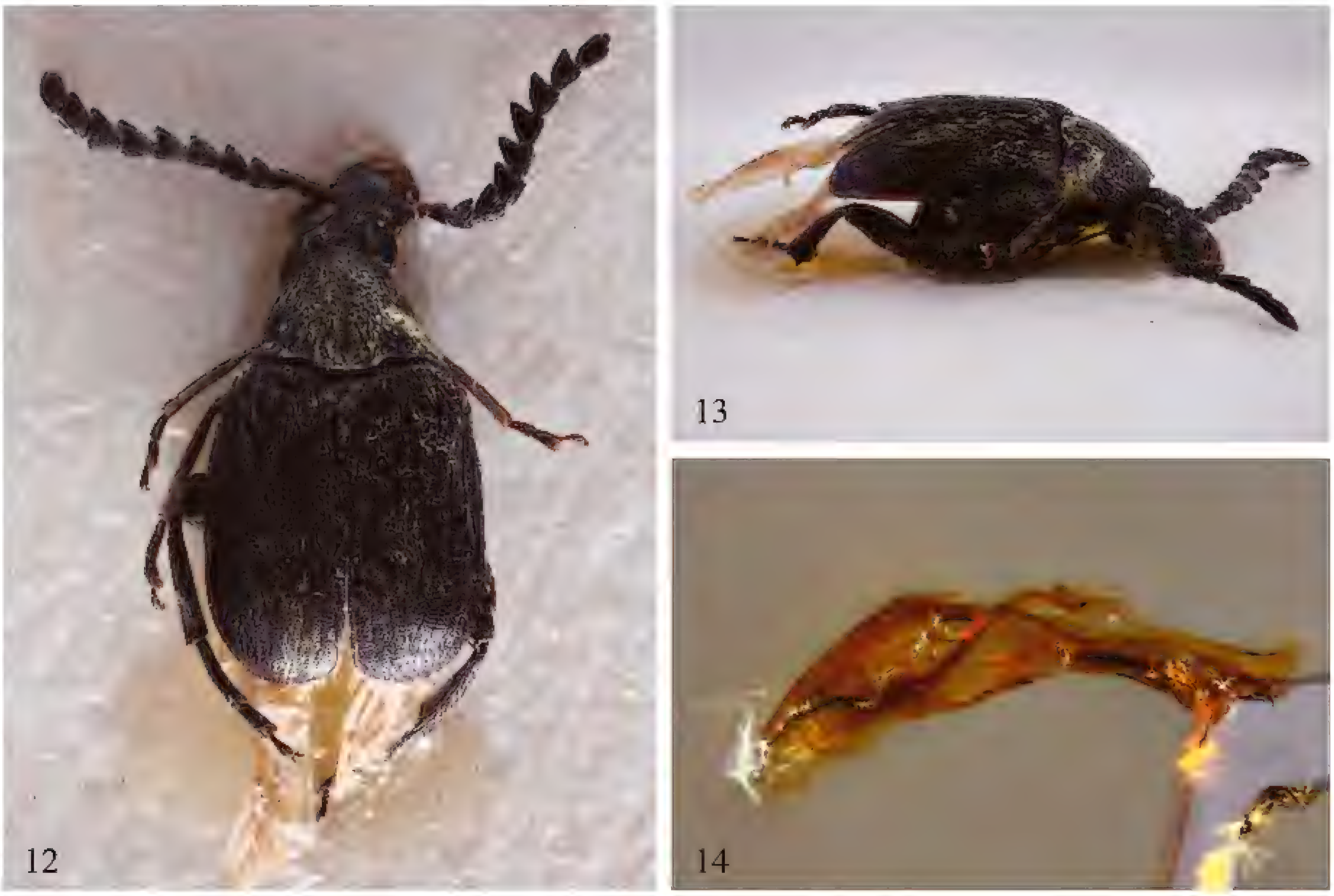
DIFFERENTIAL DIAGNOSIS. The first antennal segments of the body shape and structure of the legs, make this species look like *Bruchidius nanus* (Germar, 1824) and more widely the *nanus-tuberculatus-obscuripes* group.

Bruchidius samai n. sp. - Figs. 12–14
http://zoobank.org/4f6bb38c-2ed6-4437-88f9-604f42e71355

EXAMINED MATERIAL. Holotypus male. Turkey, vil Mersin, 8 km North Tarsus foreward Çamlayla, G. Sama legit, 02.VI.1981.

DESCRIPTION OF THE HOLOTYPE. Habitus of the male as in figures 12 and 13. Length: mm 2.5; width: mm 1.2; thus, the body appears short and oval and totally black, with the maximum width displayed behind the middle of the body and the maximum convexity at the middle of the elytra. The insect is covered all over by a very thin ashy-grey, almost uniform pubescence. The head with the clypeus is slightly longer than wider, the edge of the forehead-clypeus displays a very evident "ʌ" shape and the frontal carena is complete and evident; there is no constriction behind the eyes. The markings are deep, rough and coarse as seen throughout the rest of the body. The antennae, with the 4th and 10th segments, are completely open and go beyond the base of the elytra; they are serrated starting from the fourth segment. The 2nd segment has a spherical shape as long as wide; the 3rd segment has a triangular shape and it is almost twice longer and wider than the 2nd segment. The 4th segment is respectively 1.5 and 1.7 times longer and wider than the previous segment. The antennal segments from the 5th to the 10th have a subtriangular shape and are constant in length; the width of the segments from the 5th to the 7th increase while the width of the segments from the 8th to 10th decrease.

The prothorax presents a cone shape with sharp back angles, just longer than wider and uniformly convex from the base to the top; it displays sinuous lateral sides, also the base is straight with the central part slightly protruding. The basal edge is absent



Figures 12–14. *Bruchidius samai*. Fig. 12: habitus of the type male, dorsal view. Fig. 13: habitus of the type male, lateral view. Fig. 14: median lobe of the aedeagus.

while the apical one is incomplete and so only present in the middle part. The markings are uniform and less pronounced than on the head. The scutellum is as long as wide.

The elytra are sub-square shaped, 1.3 times longer than wider, and a little convex. The small dotted markings are simple and uniform. The humeri are bare only in the upper part. The legs have no tooth on the inside of the back femurs. It displays straight tibias, with the back ones ending with two very short black thorns a little visible and only one of them is longer than the other. The back tarsi are a little longer than the tibia. The abdomen of this specimen is unfortunately lost.

Aedeagus: median lobe is progressively enlarged from the articulation of the paramers up to the apical part. The paramers display a linear edge and the apex terminates in a sharp triangular tip; a small tip is evident at the apex. From the side the median lobe appears curved at the top part. The paramers have linear edges and have the same width along the whole length. The lobes are turned toward the inside and endowed with bristles in the upper part. The basal part holds the paramers together and consists of two segments gathered around the median lobe which continue to the apex with an uneven piece (Fig. 14).

VARIABILITY. Female unknown.

DISTRIBUTION. This new species is known only from the locus typicus: Turkey, vil Mersin, 8 km North Tarsus foreward Çamlayla.

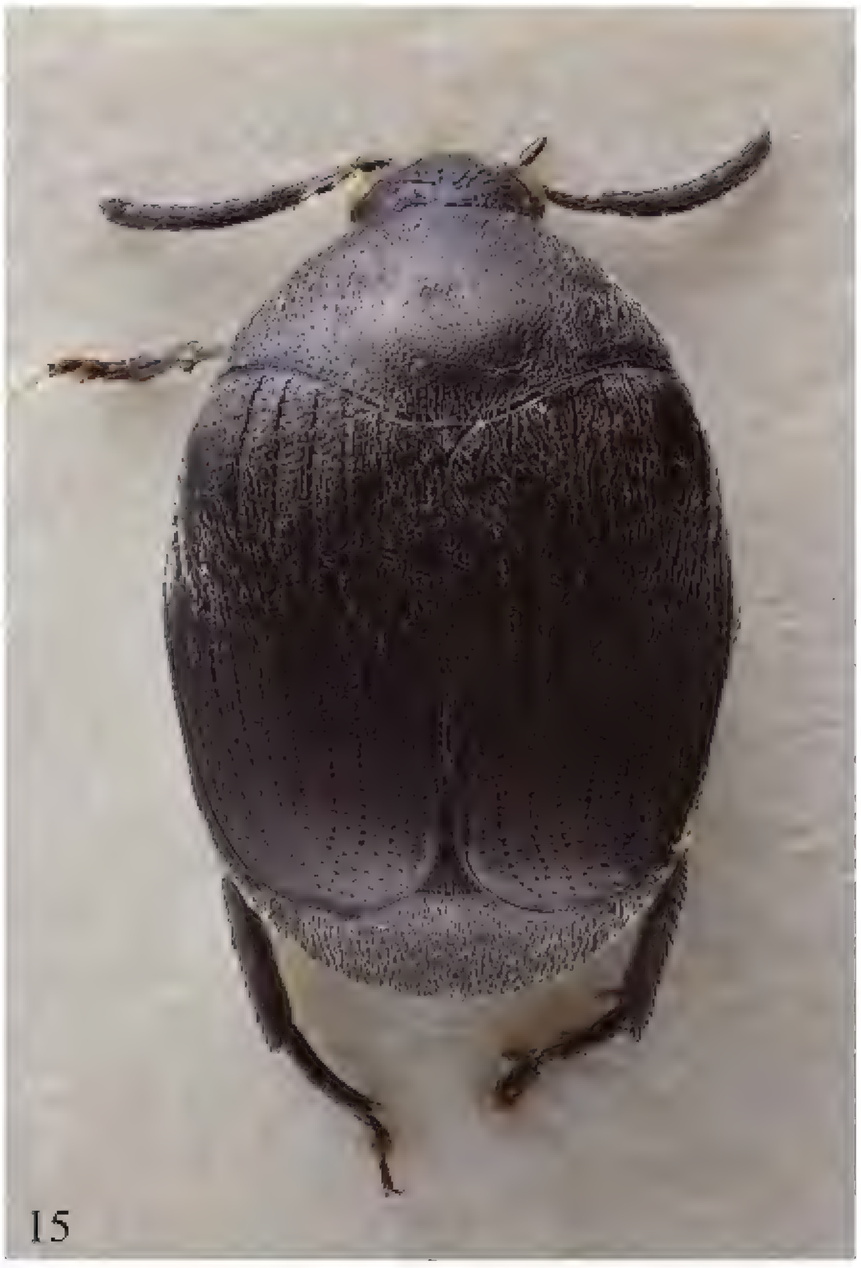
DIFFERENTIAL DIAGNOSIS. The characters of this holotype seem to set it very close to *Bruchidius reitteri* Schilsky, 1906 to which two other species can be related: *Bruchidius richteri* Ter-Minasyan, 1954 and *Bruchidius migliaccioi* Zampetti, 1998.

Genus *Spermophagus* Schoenherr, 1833

Spermophagus nicotrai n. sp.- Figs. 15, 16
= *Spermophagus* sp. Zampetti, 1988
http://zoobank.org/e07a11ef-bf2c-4754-b7cb-666a62e6408c

EXAMINED MATERIAL. Holotype female. Somalia, Afgoi, Nicotra legit, VII/XII.1937.

DESCRIPTION OF THE HOLOTYPE. Female, habitus as in figures 15 and 16. Length 2.7 mm, maximum length 1.66 mm; the shape of the body is short and oval. It is totally black with the exception of the terminal thorn on the back tibia that is a brown-red color. Short oval body, with the maximum width and the maximum convexity in the middle part of the body. It is a black insect covered by a very thin ashy-grey pubescence, barely visible and scattered. The head is a semicircular form situated behind the eyes and strongly convex. The clypeus is roughly 1.5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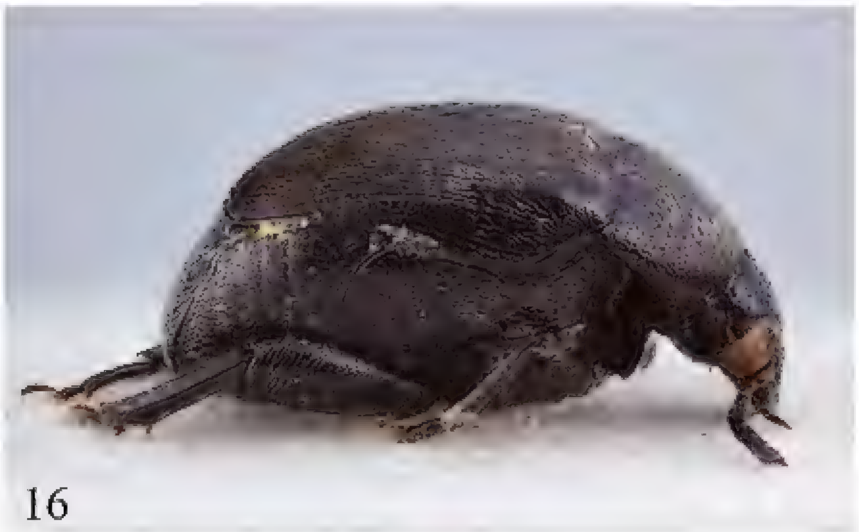
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Figures 15, 16. *Spermophagus nicotrai*. Fig. 15: habitus of the type female, dorsal view; Fig. 16: habitus of the type female, lateral view.

wider than longer. The forehead-clypeus edge is straight. The eyes are normally convex which is a typical feature of the genus. The markings are thin, dense and uniform. The antennae arrive just at the middle of the thorax; thread-like and with segments that are slightly enlarged starting from the 5th segment. The 2nd antennal segment is small, sub-spherical, slightly longer than wider; the 3rd segment is 1.3 times longer than the 2nd; the 4th segment is slightly shorter than the previous one and almost of the same width. The 5th segment is shaped like a trapezoid and it is 1.2 times wider than the previous, almost as long as it is wide. The segments from the 6th to 10th are sub-rectangular, constant in length and width, almost 1.2 times longer than wider.

The prothorax is shaped like a bell with its sides converging forward forming an arc shape from the base so that the back angles result as right angles; it is 1.8 times wider than longer. The apical and the basal edges are complete. The pronotum is uniformly convex in both directions and its base is serrated. The markings are thin composed of average-size dots like the ones on the head. The scutellum is a triangular shape with the same width and length.

The elytra are about 1.5 times longer than wider portraying their maximum convexity in both directions, in the apical half and almost flat in the basal half. The humeri are protuberant, with thin markings, shallow and uniform on the inter-striae and with clearly larger dots on the striae. All the striae are complete with the exception of the 7th and 8th which are interrupted just before the humeri, while the 9th stops at their side. The first and the second pair of legs are thin while the third pair have little swollen femurs. The tibiae are slightly enlarged and a little compressed ending with one (the presence of only one mobile thorn, since in the other tibia the mobile thorns are absent, leads to suppose that during the preparation of the specimen the mobile thorns were broken) long, strong red moveable thorn, one stronger black thorn and three smaller ones all attached on the upper side.

The pygidium is a little tilted with a curved apex. Its width is 1.4 times the length. The markings are uniform and made up of fairly large dots. The ovipositor was not extracted.

VARIABILITY. Male unknown.

DISTRIBUTION. This new species is known only from the locus typicus: Somalia, Afgoi.

DIFFERENTIAL DIAGNOSIS. This new species is somewhat similar to *Spermophagus somalicus*, which however has two red spines at the end of the tibia (Decelle, 1979), a character that is not observed in this holotype.

Protobruchus nov. gen.
http://zoobank.org/02c6a0ee-7f1d-4b85-90ce-1fdbf4c66901

Type species: *Protobruchus togoensis* n. sp.

This new genus is characterized by the combination of the following features:

- head moderately lengthened, borderless eyes for 3/5, central carena present and clearly visible, shiny and complete;
- normal antennae in the male, not combed nor clasped;
- pronotum without lateral edge;
- short, triangular protosternal process separating the protocoxae throughout the whole length;
- metasternum strongly angled from the profile;
- back femurs are slightly thickened and the dorsal carena has no teeth;
- two preapical thorns are present: a strong one typical of the species and an inside thorn, having the same dimensions, thinner and sharper but definitely bigger, typical of the genus *Bruchidius*; both thorns are the same length; the position of these thorns recalls the genus *Callosobruchus* but it is distinguished by the absence of the other characteristics.
- back tibia is straight without a carena and without terminal thorns;
- first posterior tarsus roughly 2/3 in length of the respective tibia and about 5 times the length of the tarsus.

Protobruchus togoensis n. sp. - Figs. 17–19
http://zoobank.org/ea5da563-adbb-4b9c-8913-8a2cebd9adc9

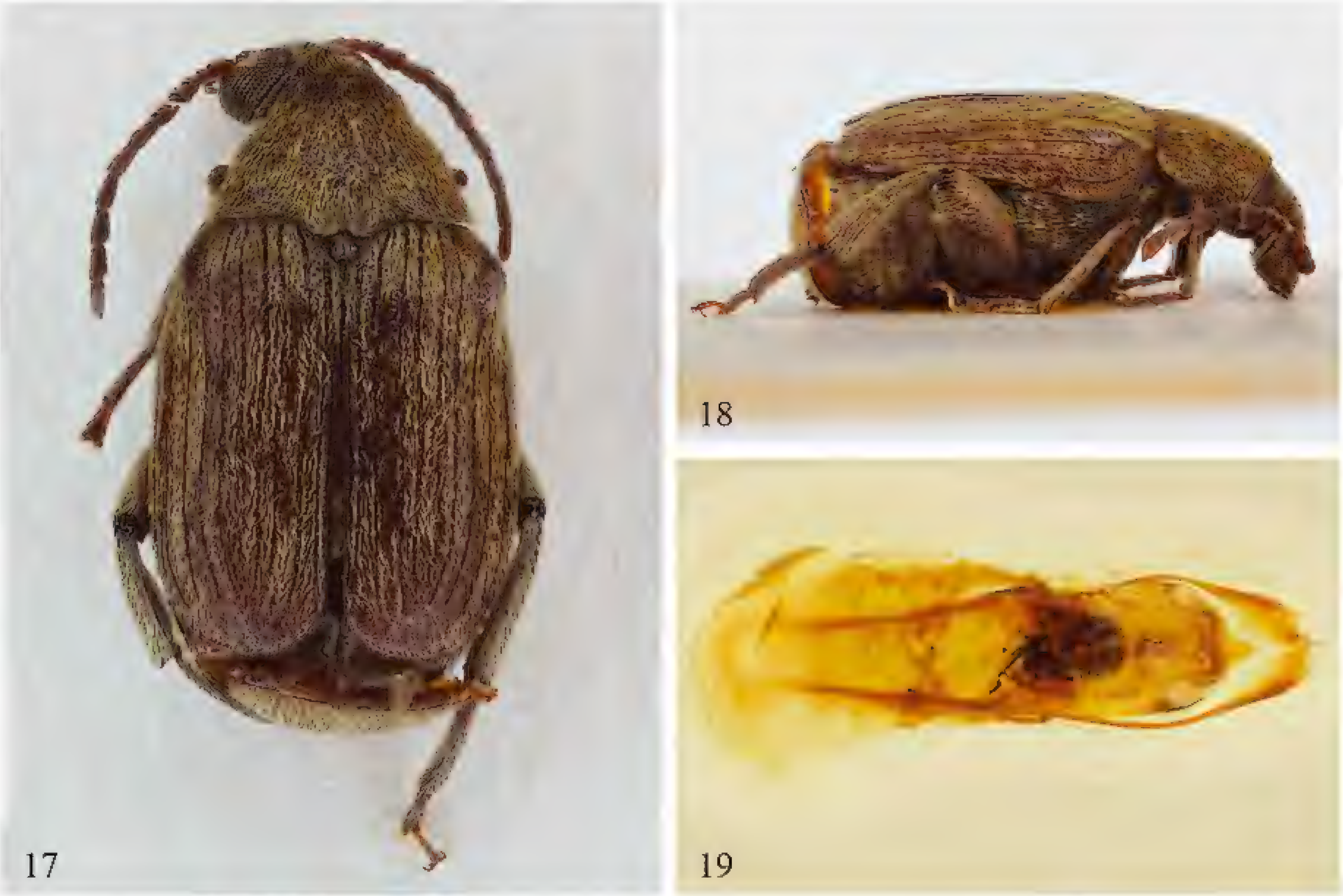
EXAMINED MATERIAL. Holotype male. Togo, Sokodé, 400 m above s.l., I.1991, Melandri legit.

DESCRIPTION OF THE HOLOTYPE. Male, habitus as in the figures 17 and 18. Length 5.8 mm, maximum width 2.7 mm; thus, the insect results having an elongated and oval shape. The body is uniformly red-brown with the exception of the head being slightly darker. It is covered by a tawny clear uniform pubescence over the whole body apart from two areas, the pygidium and a lock of thick bristles towards the scutellum, that tends to hide the underlying tegument. The head has the clypeus slightly longer than wider and the forehead-clypeus edge is arc-shaped and clearly visible. The frontal carena is robust, complete and shiny. The narrowing behind the eyes is present but not evident. The dotting patterns are marked but not very big. The antennae go beyond the base of the elytra but are shorter than half of the body: they are slightly serrated beginning from the fourth article. The second antennal segment has a spherical shape as long as it is wide; the third is triangular, narrow and elongated and it is 1.7 times longer than wider and longer about twice the second segment. The 4th antennal segment is just longer and a little shorter than the third. The antennal segments from the 5th to the 10th are subtriangular and fairly constant in length and width, as long as wide with the exception of the 10th that is slightly narrower than the previous ones and is ¼ longer than wider. The base of each segment from the 5th to the 10th increases in width, so the shape of the antennal segments changes from triangular to rectangular.

The prothorax is conic shaped with sharp back angles, 1.4 longer than wider, uniformly convex; it portrays upright sides slightly curved in the middle, the base is also straight with the central part slightly curved. The apical edge is complete while the basal one is absent. The markings are not uniform as big dots alternate with smaller dots, however, it is visibly marked as on the head. Scutellum is sub-square shaped roughly wide as it is long, covered by a dense marking similar to the one on the prothorax.

The elytra are rectangular with almost parallel sides, about 1.2 times longer than wider and flat in the central part. The striae are deep and complete, the 9th and 10th are joined at the base of the elytra. The markings are uniform as on the prothorax. Back femurs slightly thickened; two apical thorns are present, one external and robust and one internal thinner and sharp; both thorns are of the same length.

The pygidium is very inclined, practically per-



Figures 17–19. *Protobruchus togoensis*. Fig. 17: habitus of the type male, dorsal view. Fig. 18: habitus of the type male, lateral view. Fig. 19: aedeagus.

pendicular, longer than wider, convex and with a curved apex. The markings are the same as in the other parts of the body but less emphasized.

Aedeagus: median lobe is oval shaped with arched edges. The apex is thickset, enlarged and ending with a small but evident thorn. The paramers have curvilinear edges and the lobes are turned toward the inside with bristles in the apical area. The basal part holds the paramers together; these are joined around the median lobe towards half of its length (Fig. 19).

VARIABILITY. Female unknown.

DISTRIBUTION. This new species is known only for the locus typicus: Togo, Sokodé, 400 m a.s.l.

DIFFERENTIAL DIAGNOSIS. In this species there are two main characters: the first is the general structure of the body and in particular the shape of the head with typical eyes and antennae similar to the species of the genus *Pachymerus* Thunberg 1805; the second is the presence of the preapical tooth in the posterior femurs, that distinguishes the species of the genus *Bruchus* Linnaeus 1767. This new species does not have similar species to which it can be related.

CONCLUSIONS

In this study, seven species of Bruchidae new to science are described: five of them belong to the genus *Bruchidius*, one to the genus *Spermophagus* and one to the new genus *Protobruchus*, here described. Five of these species are from the Mediterranean area, *Bruchidius horshensis* n. sp., *Bruchidius lekefensis* n. sp., *Bruchidius salinaensis* n. sp., *Bruchidius bcharréensis* n. sp., and *Bruchidius samai* n. sp.; one from East Africa, *Spermophagus nicotrai* n. sp. = *Spermophagus* sp. Zampetti, 1988; one from West Africa *Protobruchus togoensis* n. sp.

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http://zoobank.org/e463b374-c552-4725-90d9-415d13382c9f

A new species of the genus *Ocenebra* Gray, 1847 (Gastropoda Muricidae Ocenebrinae) from southern Spain (Mediterranean Sea)

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ABSTRACT Based on morphological characters of the shell and animal, a small new species of gastropod of the genus *Ocenebra* Gray, 1847 (Gastropoda Muricidae Ocenebrinae), *Ocenebra aparicioae* n. sp., is here described from the infralittoral coast of Murcia, southern Spain, a poorly known area in the Mediterranean Sea, and it is compared with other close related species of the family Muricidae, such as *O. nicolai* (Monterosato, 1884), *O. helleri* (Brusina, 1865), *O. vazzanai* Crocetta, Houart et Bonomolo, 2020 and *Ocinebrina reinai* Bonomolo et Crocetta, 2012.

KEY WORDS Mollusca; Muricidae; *Ocenebra aparicioae* n. sp; Mediterranean.

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INTRODUCTION

After a series of recently published studies focused on the *Ocenebra edwardsii* complex (Barco et al., 2013a, 2013b, 2016) and on the *Ocinebrina aciculata* complex (Barco et al., 2017; Crocetta et al., 2012) and performed on the basis of molecular and morphological features, the cluttered situation of the subfamily Ocenebrinae Cossmann, 1903 in the Mediterranean Sea was partially clarified. The genus *Ocinebrina* Jousseaume, 1880 and *Ocenebra* Gray, 1847, that where until then considered monophyletic, are now separated in different clades, and the species attributed to the *Ocinebrina edwardsii* complex were placed in *Ocenebra* (Barco et al., 2016). These papers also led to some new combinations: *Ocinebrina carmelae* Cecalupo, Buzzurro et Mariani, 2008 as synonym of *Ocenebra piantonii* (Cecalupo, Buzzurro & Mariani, 2008) (Barco et al., (2013b), the validation of *Ocenebra hispidula* (Pallary, 1904) as a distinct species (Barco et al., 2013a) and the description of *Ocinebrina reinai* Bonomolo et Crocetta, 2012 in Crocetta et al. (2012) and *Ocinebrina aegeensis* Aissaoui, Barco et Oliverio, in Barco et al. (2017) as new species. However, *Ocenebra nicolai* (Monterosato, 1884), *Ocenebra helleri* (Brusina, 1865) and *Ocenebra paddeui* (Bonomolo & Buzzurro, 2006) still need molecular analysis.

The study of the area of Isla del Fraile and other enclaves in the Hornillo Bay (Murcia) by scuba diving in precoralligenous and bioclastic bottoms led to the finding of several shells and living specimens of small muricids that did not fit with any known species and are here described as a new species. Considering plesiomorphic similarities with the *Ocenebra edwardsii* complex, like the colour of the animal, the presence of a varicose external lip, the shape, the sculpture of the shell and the absence of labral tooth (Barco et al., 2016) this newly described species is placed in the genus *Ocenebra*.

MATERIAL AND METHODS

All the samples where handpicked during scuba dives in Isla del Fraile, a small close-shore island with coordinates 37°24'31"N, 1°32'48"O and other similar enclaves in the Hornillo Bay (Águilas, Murcia, Spain) at depths between -6 and -20 m on rocks in precoralligenous and bioclastic bottoms between October 2018 and November 2019.

The samples were studied and photographed under a stereo microscope and some specimens were maintained in aquarium for the study of the animal.

Nomenclature and systematics are applied based on MolluscaBase (2020).

ABBREVIATIONS AND ACRONYMS. Following Merle (2001, 2005) to define spiral sculpture: Abapical infrasutural secondary cord (abis); adapical infrasutural secondary cord (adis); infrasutural primary cord (IP); primary cord (P); secondary cord (s). Other abbreviations and acronyms: Author's personal collection (APC); maximum height (H); Museo Nacional de Ciencias Naturales, Madrid, España (MNCN); Muséum National d'Histoire Naturelle, París, France (MNHN); maximum width of the last teleoconch whorl (W).

RESULTS

Systematics

Classis GASTROPODA Cuvier, 1795
Subclassis CAENOGRASTROPODA Cox, 1960
Superfamilia MURICOIDEA Rafinesque, 1815
Familia MURICIDAE Rafinesque, 1815
Subfamilia OCENEBRINAE Cossmann, 1903
Genus *Ocenebra* Gary, 1847

TYPE-SPECIES. *Murex erinaceus* Linnaeus, 1758 (by monotypy)

Ocenebra aparicioae n. sp. (Figs. 1–29)
http://zoobank.org/f0e877c3-ac1a-4a6b-afa9-9f1bdc15c97f

TYPE LOCALITY. Hornillo bay, Águilas, Murcia, Spain, sciafilic-precoralligenous bottoms between -6 and -20 meters deep.

ETYMOLOGY. The species is dedicated to the author's mother, Concepción Aparicio.

TYPE MATERIAL. Holotype H = 9.18 mm, W = 4.75 mm (MNHN-IM-2000-35617) (Figs. 1–5); Paratype 1 H = 7.00 mm W = 3.85 mm (MNCN 15.05/XXXX) (Figs. 9, 10); Paratype 2 H = 9.29 mm W = 5.15 mm (APC) (Figs. 11, 12); Paratype 3 H = 8.92 mm W = 4.21 mm (APC) (Figs. 18-19); Paratype 4 H = 8.72 mm W = 4.13 mm (APC) (Figs. 13, 14); Paratype 5 H = 8.03 mm W = 4.14 mm (APC) (Figs. 16, 17). All from type locality.

OTHER STUDIED MATERIAL. Other 13 living specimens and other 21 shells, including 3 juveniles.

DESCRIPTION OF THE HOLOTYPE. Shell of small size for the genus, with 9.18 mm high and 4.75 wide. Solid and compact of romboidal/fusiform shape with 4.5 convex teleoconch whorls, last whorl consisting in 2/3 of the total shell length. Protoconch paucispiral (Figs. 4, 5) with 1.25 whorls of 700 μm in height and 600 μm wide, with a dark brown color, rounded, with the nucleus inclined to the center around 30º, smooth surface with a very fine irregular granularity, observable only under high magnifications. Teleoconch amber yellow with a darker apex and dark brown spots on the tubercles. Spiral sculpture is strong and regular, consisting of adis-IP-abis-P1-s1-P2-s2-P3-s3-P4-s4-P5-s5-P6-s6-ADP-MP-ABP (Fig. 15) in those shells where all cords are clearly manifested. Primary cords are much thicker and evident than secondary cords. P1 is the most prominent of the primary cords. Abis, s1, s4 and s6 are weaker and hardly noticeable, as well as the siphonal spiral cords, that are more diffuse, while adis, s2, s3 and s5 are the most evident secondary cords, and are always clearly present. There are 10 strong axial ribs in the last whorl and strong, thick, smooth and rounded nodes raise above the primary spiral cords when they overlie the axial ribs, giving it a cancellated/mamillated appearance, dark brown coloured, fading in the intercostal space. These tubercles appear also in the secondary cords, especially in adis, s2, s3 and s5. Suture is not deep, axial ribs generally touch between whorls. External lip with a thick and jagged varicosity. Siphonal canal short, strong, ventrally sealed in the adults by a sheet coming out the columelar edge. Aperture oval and narrow, white, with 5 internal denticles, equal in size (D1–D5). Columellar lip narrow and adherent, smooth and white. The soft parts (Figs. 6–8) present a translucent cream to yellow pigmentation, splashed with small shiny white-yellow spots concentrated in the foot and the tentacles, the latter being long, translucent and densely spotted with bright yellow especially from the eye to the end of the tentacle. Operculum corneus and eccentric, with a soft brown to orange colour.

VARIABILITY. As typical in the group, intraspecific variability is observable, but less markedly compared to other species of the genus.

The observed shell size range was between 7.52 to 10.30 mm high and 3.85 to 5.51 mm wide, with 4.5 to 5 teleoconch whorls. Axial ribs are between 9-11 in the last whorl, and rarely (only in 3 of the specimens studied) an erratic varicosity in the last whorl is observed. Abis, s1, s4 and s6 can sometimes be unnoticeable. The aperture in less mature shells can occasionally be pale brown or purple.

In some specimens the shape can be more rhomboidal-like or more fusiform. The colour of the shell can include the presence of a cream to white spiral line along P2 or in both P2 and P5, where the brown colour of the tubercles on these cords can fade with the white (Figs. 22, 23) or either still be present over the white band (Fig. 28, 29). It has also been observed the almost complete vanishing of all the brown spots on the tubercles, leading to a uniform amber colour, but this condition as only been observed in one specimen which could be considered old and sligthly eroded.

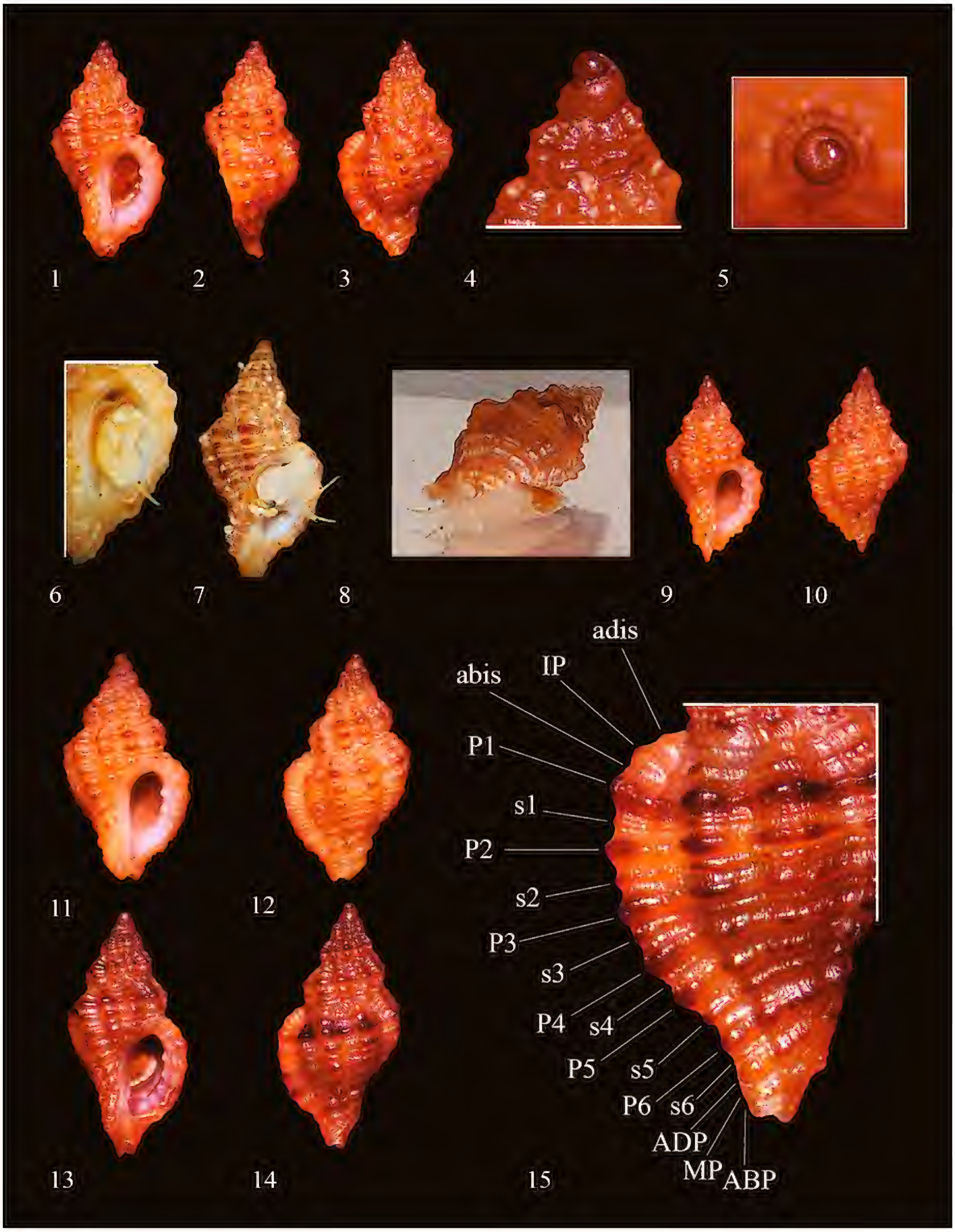
DISTRIBUTION AND BIOLOGY. The new species seems to have preferences to well developed scapes, with high bentic organism density (sciafilic/precoralligenous community) at depths between 6 and 20 m with moderate hydrodinamism and a complex geomorphology, where it appears on rocks highly affected by biologic activity, piled in such way they provide abundant wide shelters and space between them.

COMPATIVE NOTES. The most similar related species to *O. apariciae* n. sp. is *O. nicolai* (Monterosato, 1884) whose sculpture tends to be less marked, more irregular and does not develop nodules, has a lower number of axial ribs and being the suture deeper, leading to more convex whorls. *Ocenebra nicolai* seems to be distributed in the Ionian, Thyrrhenian and Ligurian seas (Russo, 2018), however its presence should not be discarded in the Adriatic Sea, and in the Alborán Sea with an interesting red coral bottoms population in the Gibraltar strait, along the Morocco's side, which need further studies. Despite this, *O. nicolai* is not signaled in the coasts of Andalucía (Gofas et al., 2011) but it is considered as a possible deep water ecophenotype of *O. edwardsii* (Payraudeau, 1826). This could be explained by the fact that only a deep water or intermediate form of *O. edwardsii* was actually studied and not the actual *O. nicolai*, as could be argued by the specimen figured, which does not match well with the classical interpretation of this taxon.

Another similar species is *O. helleri* (Brusina, 1865), whose taxonomy is confusing and still under discussion (Russo, 2018). It is present in the Tyrrhenian and Adriatic seas, and recently cited in Hellenic waters (Mbazios et al., 2020) with a shell which tends to have a more elongated shape, also a deeper suture and more convex whorls, with a more prominent siphonal canal, presenting also a higher number of spiral cords and 6 up to 7 internal denticles, unlike *O. aparicioae* n. sp. that shows only 5.

It is interesting to note that this species seems to share a homoplasic feature with *Ocinebrina reinai* Bonomolo et Crocetta, 2012 (Figs. 30, 31) in the presence of dark spotting on the nodes of the spiral cords, making the shells look similar at first sight, but easily distinguishable by the strong and jagged varix in the outer lip of *O. aparicioae* n. sp., being much weaker or absent and barely crenulated in *Oc. reinai*. The difference between primary and secondary cords of the spiral sculpture is more obvious in *O. aparicioae* n. sp., resulting in a more cramped appearance on the sculpture of *Oc. reinai*. *Ocinebrina reinai* shows 6 to 7 internal denticles, while *O. aparicioae* n. sp. always shows 5. Other confirming aspect is the colouration of the animal that appears reddish in *Oc. reinai* and all the components of the *Oc. aciculata* complex, while it is translucent yellow in *O. aparicioae* n. sp.

During the printing phase of this article, the report of a new species of the genus *Ocenebra* was received: *O. vazzanai* Crocetta, Houart et Bonomolo, 2020. This new species seems to be endemic of a submarine cave of the Messina Strait area and shows a similar aspect with *O. aparicioae* n. sp. However, *O. aparicioae* n. sp. differs from *O. vazzanai* in size, being much smaller, since *O. vazzanai*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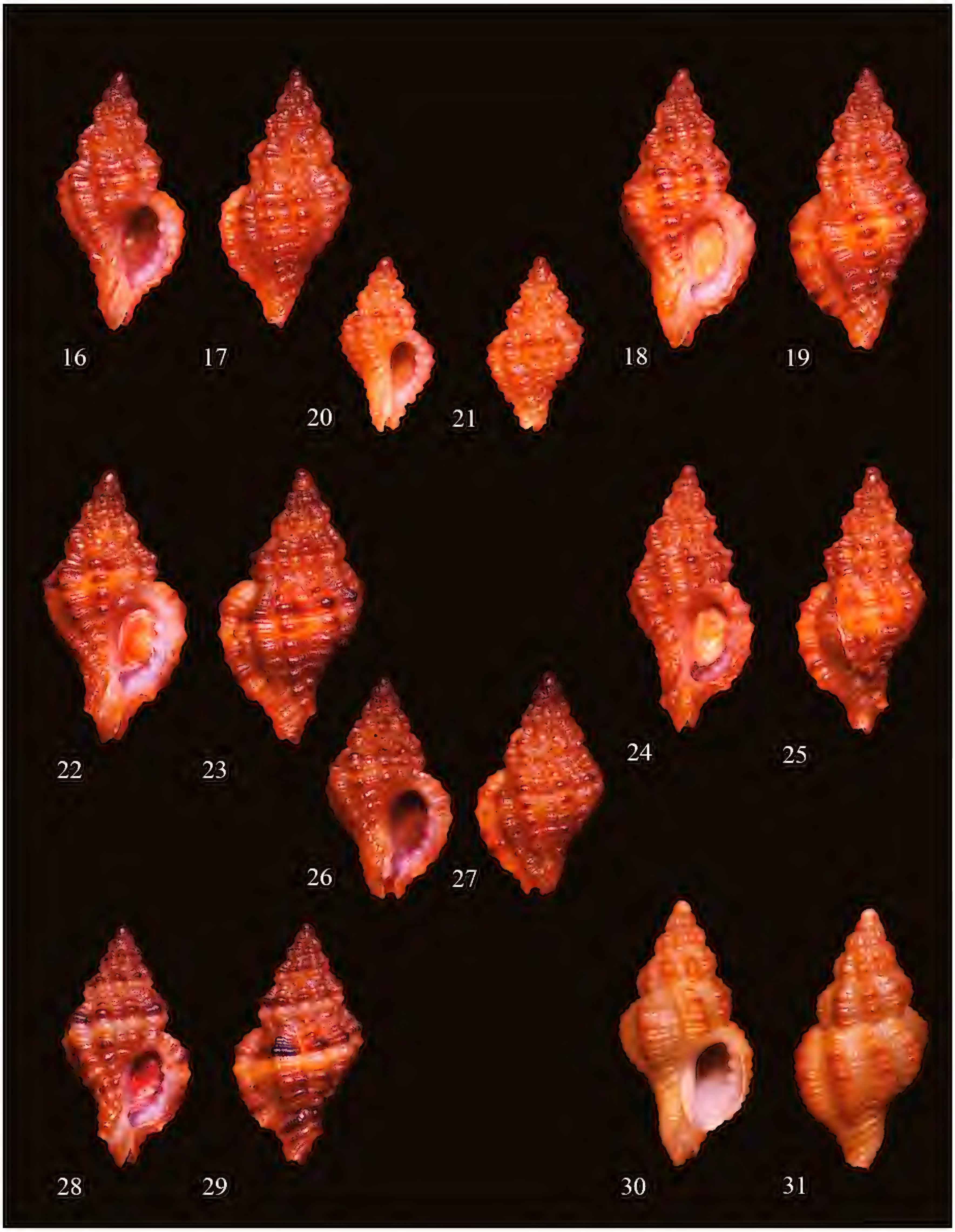
Figures 1-15. *Ocenebra aparicioae* n. sp., all from the type locality: Hornillo bay, Águilas, Murcia, Spain. Figs. 1-5: holotype, H = 9.18 mm. W = 4.75 mm. (MNHN). Figs. 4, 5: detail of the protoconch. Figs. 6, 8: detail of the animal. Figs. 9, 10: paratype 1, H = 7.00 mm. W = 3.85 mm. (MNCN). Figs. 11, 12: paratype 2, H = 9.29 mm. W = 5.15 mm. Figs. 13, 14: paratype 4, H = 8.72 mm. W = 4.13 mm. Fig. 15: Outline naming the spiral sculpture of the last whorl.



Figures 16-29. *Ocenebra aparicioae* n. sp., all from type locality. Figs. 16, 17. paratype 5, H = 8.03 mm. W = 4.14 mm. . Figs. 18, 19: paratype 3, H = 8.92 mm. W = 4.21 mm. Figs. 20, 21: juvenile H = 6.50 mm. W = 3.31 mm. Figs. 22, 23: H = 8.38 mm. W = 4.36 mm. Figs. 24, 25: H = 8.19 mm. W = 4.32 mm. Figs. 26, 27: H = 7.64 mm. W = 4.18 mm. Figs. 28.29: H = 7.88 mm. W = 4.34 mm. Figs. 30, 31: *Ocinebrina reinai* Bonomolo et Crocetta, 2012, topotype H = 9.77 mm. W = 4.88 mm. Secche di Tor Paterno, -35 m.

is in average twice as big and developes one more whorl, the colour, being the apex dark brown, is in contrast with the lighter teleoconch, while it is more uniform in *O. vazzanai.* The shape and sculpture are also different, as *O. vazzanai* shows a deeper suture, spiny appearance, specially in the last whorls, with a taller and more expanded labral varix and a wider apperture with a spiny edge. *O. aparicioae* also shows more spiral sculpture, with a prominent and always present adis. Habitat depth range seems to be also different, living *O. vazzanai* at around 50 m while *O. aparicioae* n. sp. has not been found under 20 meters.

As the shell of *O. aparicioae* n. sp. is so particular and does not resemble like any other not mentioned Mediterranean or northeastern Atlantic species, a comparision with other species is considered not required, excluding also the possibility of being an alien species.

DISCUSSIONS AND CONCLUSIONS

Evident morphological divergences have been observed between specimens studied and their congeneres and allowed to unequivocally distinguish and describe this taxon as new, being the most notable characters its small size, the marked regular axial and spiral sculpture leading to prominent and smooth nodes, the strong difference between primary and secondary cords and the constant tendency of this secondary cords to appear more or less marked depending on the sector, the shape and the striking colouration of the shell and soft parts. It is likely to complement with molecular analysis all these morphological characters above outlined in further studies.

Size is a remarkable factor, being this new species much smaller in average compared to its mentioned congeners. Considering only complete and adult specimens, the height average of the 34 shells measured is 8.78 mm, with only 2 shells reaching one centimeter (max. height observed was 10.30 mm) making it the smallest species of the genus.

In the studied area, at the lowest depth sampling ranges, few dead shells with hermit crabs of *O. edwardsii* were found, coming from shallower levels. These shells showed a thicker shell, with a much wider and purple aperture, clearly smaller protoconch, lower spiral sculpture with a slight difference between primary and secondary cords, and a less numerous (7–8 axial ribs in the last whorl) but higher and broader axial sculpture. Despite the fact that *O. edwardsii* is a highly variable species, *O. aparicioae* n. sp. does not fit to the characteristics of any of its forms.

Moreover, the shape and number of whorls of the protoconch of *O. aparicioae* seem to imply that a non planktotrophic larva is involved, which suggests a low dispersal capability of this species.

The new species seems to be rare, notwithstanding that the sampling was complicated by the environmental difficulties of the studied area especially in Isla del Fraile, where sciafilic algae and precoraligenous community dominate the bottom, and the abrupt geomorphism and the abundant calcareous organisms compound a complex seascape with many cracks and hiding places. The most abundant organisms in this community were represented by rhodophytic and pheophytic algae, colonial stony corals (*Hoplangia durotrix* Gosse, 1860), bryozooans as *Myriapora truncata* (Pallas, 1766), *Reteporella grimaldii* (Jullien, 1903) and *Bugula* sp., ascidians as *Ascidia* sp., *Brotryllus* sp., *Clavelina* sp., *Didemnum* sp., *Halocynthia papillosa* (Linnaeus, 1767)…), sponges as *Clathrina* sp., *Cliona* sp., *Chondrosia* sp., *Crambe crambe* (Schmidh, 1862), *Dysidea* sp., and *Phorbas* sp., *Sycon* sp., polychaetes and abundant bivalves attached to the rocks, like *Barbatia barbata* (Linnaeus, 1758), *Arca noae* Linnaeus, 1758, *Cardita calyculata* (Linnaeus, 1758), *Striarca lactea* (Linnaeus, 1758), *Lima lima* (Linnaeus, 1758), *Mimachlamys varia* (Linnaeus, 1758), *Talochlamys multistriata* (Poli, 1795) of which *O. aparicioae* n. sp. may feed upon. There are also gastropods such as *Calliostoma* sp., *Gibbula* sp., *Jujubinus* sp., *Raphitoma* sp., *Alvania* sp., *Tritia* sp., *Naria spurca* (Linnaeus, 1758), *Luria lurida* (Linnaeus, 1758), *Fusinus cretellai* Buzzurro et Russo, 2008, *Muricopsis cristata* (Brocchi, 1814), among others, compounding a very complex habitat ideal for many other species.

It is suitable to say that this specific habitat tastes, in addition to the lack of study of the area in this ambit and the probable limited range distribution due to a non planktotrophic development, may be the reason why this species was not noticed before. This reminds us that restricted and specific enclaves can be potential reservoirs for unknown species, even although being a species that lives close to the shore in shallow waters and belonging to a generally well known yet complex family in the Mediterranean as the Muricidae.

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Diatoms diversity in Oubeïra Lake, northeastern Algeria

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ABSTRACT Mediterranean wetlands are currently subjected to habitat loss and degradation derived from pollution, climate change, eutrophication and the occurrence of exotic species as the most important threats, affecting numerous taxonomic groups. Different tools are being used to assess water quality conditions in these environments, including physicochemical measurements and biological indicators (fish, invertebrates, and diatoms). We aim to study the diversity and ecology of the diatom assemblage inhabiting the RAMSAR site Oubeïra Lake in northeastern Algeria, contributing to the catalogue of diatoms recorded for Algeria. The identification of the morphological characters allowed us to make an inventory of 18 genera of diatoms belonging to 13 families of diatoms. *Navicula and Cymbella* resulted in the most abundant genera in the two studied stations during February, June, and August over two years (2017, 2018). The diatom community is structured, with a diversity index (H) equal to ~2.30.

KEY WORDS Algae; PNEK; polluosensitive; Bacillariophyta; Ramsar.

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INTRODUCTION

Aquatic ecosystems are subject to multiple pressures from both natural and anthropogenic sources. Factors such as drought, water transfers, eutrophication and the increase in the amount of organic matter due to agricultural and livestock pressures, generate a worsening of the ecological status that affects the communities of organisms associated with these ecosystems.

Diatoms (Bacillariophyta) are organisms distributed in a wide variety of environments around the world, both in aquatic (freshwater and marine) and terrestrial ecosystems. They constitute an enormously diversified group, with ca. 200,000 different species worldwide. Despite their ecological importance and great diversification in the world's aquatic ecosystems, the diatoms of many regions of the world remain virtually unknown. In Algeria, Baudrimont (1974) made a first review of the diatoms historically recorded, confirming that the first systematic algal studies of the region date back to the 1930s. Excluding fossil forms, a total of 400 species of continental diatoms have now been recorded in Algeria, with notable contributions by the eminent archaeologists (Belloc, 1893; Debray, 1897). As for the studies of fossil diatoms, the work of (El Ouahabi et al., 2008) on the diatomites of the Boudinar basin is a primary source. The applicability of biological methods for monitoring water status using diatoms has been successfully tested in several hydrographic basins (Fawzi et al., 2001; Nehar et al., 2015). As a whole, the diatom flora of the region is characterized by the predominance of cosmopolitan elements, with planktonic and benthic communities strongly influenced by nutrient concentrations and, above all, by the presence of electrolytes, with clear environmental gradients associated with the presence of different types of cations.

The objective of this work is to perform preliminary characterization of the diatom flora identity at one of the most important lakes at the national and international level, which is the RAMSAR site Oubeïra Lake in northeastern Algeria.

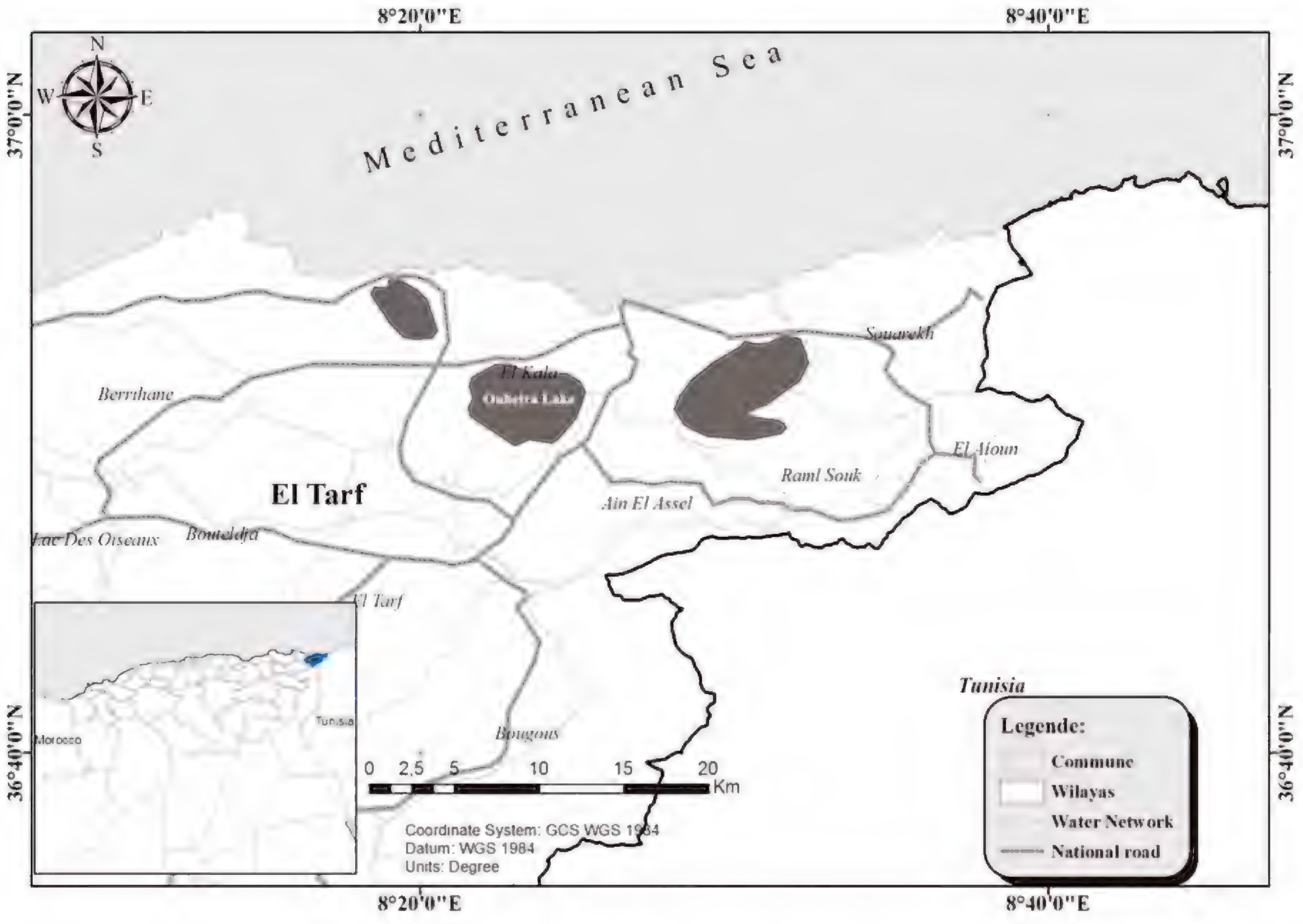
MATERIAL AND METHODS

Study area

Oubeïra Lake is located in northeastern Algeria (36°50'N, 8°23'E); it is part of the El-Kala National Park (NPEK). Oubeïra Lake has been classified as a RAMSAR site since 4 November 1983. It is a naturally occurring, permanent freshwater body with an area of 2257 ha and a depth of 4 m (Slimani, 2009). Rich in fish (carp); it is a reception area for various species of piscivorous birds such as gulls, seagulls, cormorants or ospreys (Chalabi et al., 1985). The catchment area covers an area of 9900 ha. Oubeïra Lake is a freshwater lake with no flow towards the sea. The Demnet Erihane wadi to the north, the Boumerchène wadi to the northeast, the Wadi Day Graa to the east and the Wadi Messida to the south are the main wadis that feed the lake. During the rains, the waters of Oued El Kebir pass through Oued Messida to reach Oubeïra Lake and are fed by the Monts de la Chèffia (Marre, 1992). When Wadi el Kebir is at its lowest level, in summer, the waters flow in opposite directions (Joleaud, 1936). These waters are found in the sea near Wadi Mafragh. This simplified schema obviously can not reflect the complexity of existing hydrological exchanges (Messerer, 1999).

Physicochemical parameters

The physicochemical analysis of water in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Mediterranean Sea
Souarekh
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Oubeïra Lake
Berrihane
El Tarf
El Aioun
Raml Souk
Ain El Assel
Lac Des Oiseaux
Bouteldja
El Tarf
Morocco
Tunisia
Bougous
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Datum: WGS 1984
Units: Degree
Tunisia
Legende:
Commune
Wilayas
Water Network
National road

Figure 1. Location of Oubeïra Lake, El Tarf, Algeria (ArcGIS, 2018, modified by Chabaca Hasna).

Oubeïra Lake is carried out in the field with a multiparameter (pH, temperature, conductivity). We called on a private water analysis laboratory for the other physicochemical parameters

Collection and preparation of diatoms

We sampled natural substrates at the edge of the lake collecting biofilm by employing toothbrushes. The collected samples were placed in glass bottles filled with water from the sampling sites, adding neutralized formalin to 10%. In the laboratory, samples were treated with boiling hydrogen peroxide (30%) for 90 minutes to degrade the organic matter, and for five additional minutes with boiling hydrochloric acid (35%) to remove the carbonate inclusions. Then, the samples were subjected to a series of centrifugations for five minutes at 2500 rpm and a succession of rinses with distilled water (3 times). An aliquot of the cleaned sample was deposited on a coverslip, dehydrated on a hot plate and mounted with Naphrax resin on a slide (Unité de recherche REBX, 2013 adapted).

Diatom identification

We performed a microscopic examination of the permanent slides obtained using a LEICA DM 5000 optical microscope. Subsequently, we identified and counted taxa through an immersion oil lens (1000x). In total, on each slide, we identified at least 400 valves based on previous works by (Noël, 1982; Krammer & Lange-Bertalot, 1988, 1991a; Rumeau & Coste, 1988; Meddour, 1988, 1999; Hartley et al., 1996; Al-Asadi et al., 2006; Taylor et al., 2007; Lange-Bertalot et al., 2009; Bey & Ector, 2013; El Haouati, 2015; Taylor & Cocquyt, 2016).

RESULTS

Physicochemical parameters

The physicochemical parameters of Oubeïra Lake (Table 1) vary according to the season. The average temperature of the water is 21.5 °C, with a maximum value of 30 °C during the summer period (June, July, and August) and a minimum value of 15 °C during the winter period (January).

The diversity of benthic diatoms of Oubeïra Lake

According to our observations, the community identified at Oubeïra Lake is typical of fresh and

Year	2017						2018					
Month	Feb		Jun		Aug		Feb		Jun		Aug	
Station	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T°C	16	16	30	30	30	30	16	16	30	30	30	30
DO	12	12	7	7	5	5	12	12	7	7	5	5
pH	7	7	8	8	8	8	7	7	8	8	8	8
Orthophosphates	2	2	4	4	10	10	2	2	4	4	10	10
Nitrates	30	30	0	0	30	30	30	30	0	0	30	30
Nitrites	2	2	1.9	1.9	3	3	2	2	1.9	1.9	3	3
SM	10	10	53	53	42	42	10	10	53	53	42	42

Table 1. Physicochemical parameters of Oubeïra Lake during 2017, 2018.

Year	2017						2018					
Month	Feb		Jun		Aug		Feb		Jun		Aug	
Station	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
S	17	16	13	15	16	16	14	15	14	14	17	17
Diversity	2.331	2.323	2.33	2.277	2.41	2.434	2.133	2.211	2.213	2.223	2.311	2.255

Table 2. Shannon-weaver (H) diversity index and equitability of Oubeïra Lake.

Year	2017						2018				
Month	Feb		Jun		Aug		Feb		Jun		Aug
Station	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1
Amphora	3.96	2.237136465	5.620608899	3.303964758	3.95480226	3.166226913	3.872437358	2.202643172	5.970149254	4.275534442	4.022988506
Brachysira	3,68	2,013422819	4,683840749	2,202643172	2,824858757	3,957783641	2,733485194	3,303964758	3,731343284	2,375296912	3,735632184
Caloneis	7,08	6,711409396	5,854800937	7,709251101	5,649717514	8,179419525	4,555808656	7,04845815	7,462686567	8,313539192	6,896551724
Ctenophora	0.283286119	0	1.170960187	0.8810572687	0	0	0	0	1,243781095	0.9501187648	0
Cymbella	25.49575071	26.84563758	18.735363	22.02643172	18.36158192	10.55408971	29.61275626	27.53303965	14.92537313	18.76484561	20.11494253
Cyclotella	9.915014164	7.158836689	11.70960187	14.0969163	8.474576271	10.55408971	9.111617312	8.810572687	11.19402985	16.62707838	12.93103448
Diatoma	0,566572238	0,4474272931	0	0	1,412429379	0,7915567282	0,4555808656	0,4405286344	0,2487562189	0,2375296912	1,149425287
Diploneis	0.566572238	0.2237136465	0	0	0.5649717514	0,5277044855	0	0	0	0	0.8620689655
Fragilaria	4,249291785	3,803131991	5,386416862	4,405286344	5,649717514	5,013192612	4,555808656	4,845814978	6,218905473	6,413301663	4,310344828
Gomphonema	0.8498583569	2.237136465	0	0,2202643172	1.412429379	2,638522427	0,6833712984	1.101321586	0	0	0.5747126437
Gyrosigma	11.33144476	7.606263982	9,601873536	8,810572687	9,88700565	10.55408971	13.66742597	9.691629956	9,950248756	9.501187648	8.620689655
Melosira	2,83286119	3,803131991	4,918032787	3,303964758	4,237288136	5,277044855	1,59453303	0,8810572687	0	0	1,149425287
Navicula	14.16430595	15.21252796	18.735363	16.51982379	19.7740113	19.78891821	15.9453303	16.96035242	27.36318408	17.33966746	20.11494253
Neidium	0	0	0	0	0	0	0	0	0,7462686567	0,4750593824	0,2873563218
Nitzschia	8,498583569	11,63310962	8,196721311	11,01321586	9,88700565	13,19261214	10,02277904	11,01321586	7,213930348	10,6888361	10,05747126
Pinnularia	1.699716714	3.355704698	1.8735363	2.202643172	2.824858757	2.110817942	0	2.202643172	1,243781095	1.187648456	2.011494253
Surirella	0.566572238	1.565995526	0	0.6607929515	0,8474576271	1,055408971	0,9111617312	0.4405286344	0	0	0.2873563218
Synedra	4.249291785	5.14541387	3.512880562	2.643171806	4.237288136	2.638522427	2.277904328	3.524229075	2.487562189	2.850356295	2.873563218

Table 3. Average frequency of diatoms identified in two stations at Oubeïra Lake during 2017-2018.

brackish waters. We identified 18 genera belonging to 13 families of diatoms, two genera belonging to the centric morphology (*Cyclotella* and *Melosira*) and 16 genera are pennate. This form dominated both two stations of Oubeïra Lake. During the years 2017 and 2018, the genera *Cymbella* and *Navicula* dominatedthe two stations of Oubeïra Lake. *Caloneis*, *Cyclotella*, *Gyrosigma*, and *Nitzschia* are present with average rates, the genera least present in all the stations are: *Ctenophora*, *Diatoma*, *Diploneis*, and *Neidium*.

The Shannon index calculated according to diatom surveys (Tables 2, 3) shows that in the year 2017, February S1 and August S1, S2, are the most diverse in diatoms (17,16,16 genera of diatoms respectively), by contrast in 2018, the richest month in diatoms with 17 genera is August (S1 and S2).

DISCUSSION AND CONCLUSIONS

Our study was conducted at Oubeïra Lake, the physicochemical characteristics change according to the sampling station and period, the water temperature of the lake varies from 15 ° C in winter to 30 ° C in summer. The results are similar to the works (Bensafia, 2005; Amri, 2008; Sehili, 2008; Djabourabi, 2014) that have been carried out at the Oubeïra Lake, as these seasonal variations allow a good oxygenation of the lake water (Aquaportal, 2016). The average value of the hydrogen potential is slightly alkaline (8.1). This alkalinity could be due to the increase of the diatom communities as reported (Seyni, 2006) and by an increase of oxygen in the water and by CO2 consume through photosynthesis (Stum & Morgan, 1991; Martin, 2004). Nutrients are important to the development of photosynthetic microorganisms including diatoms, the orthophosphate reaches a maximum concentration in summer (August) with 10 µmol/1. This value would come from the fine sediments which act as accumulator of this element under the usual oxidiz-

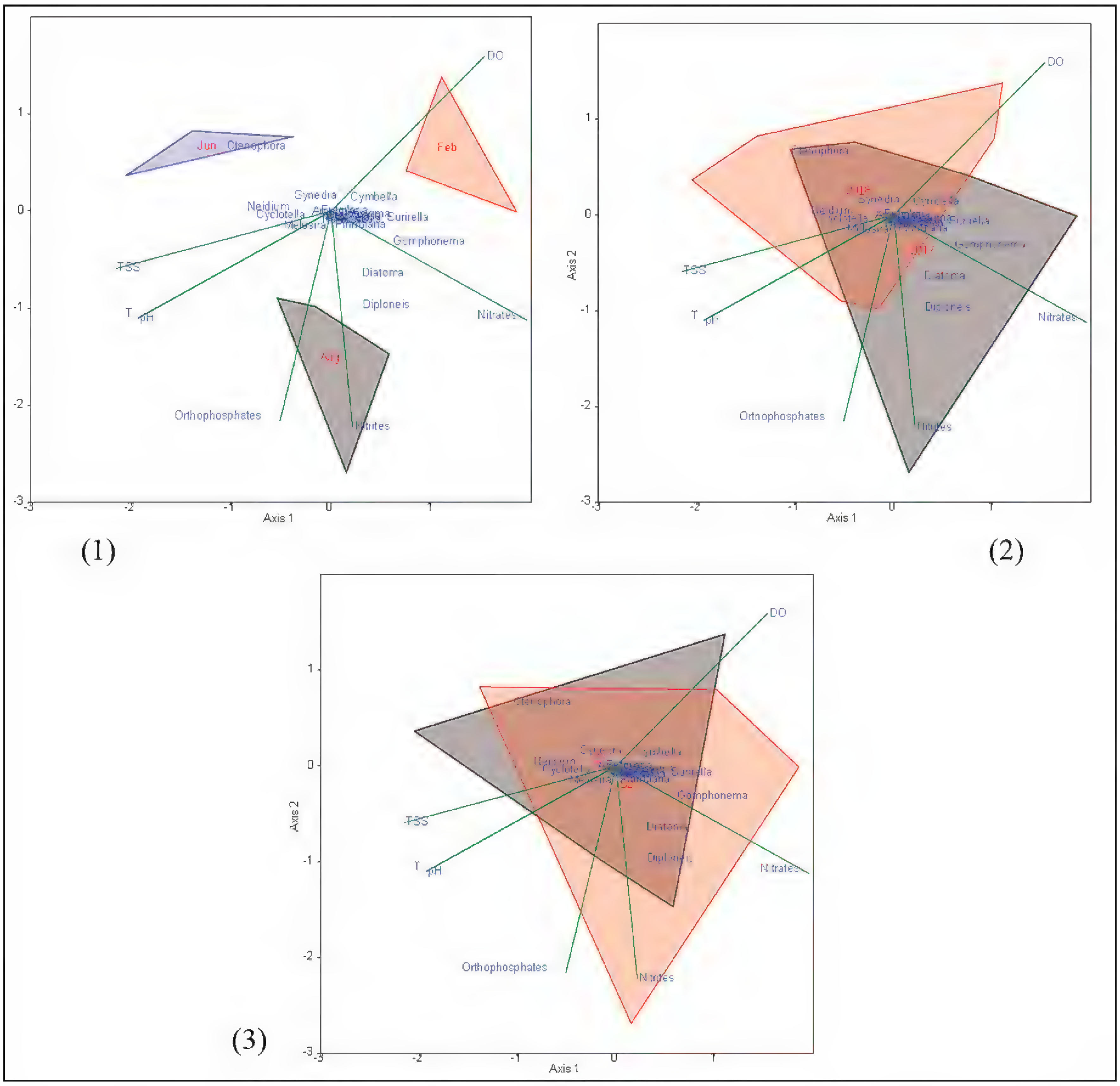

Figure 2. Canonical Correspondence Analysis (CCA) based on correlation between diatoms density and the environmental parameters from Oubeïra Lake at two stations (S1 and S2), during February (Feb), June (Jun) and August (Aug), over two years (2017 and 2018). (1) Canonical Correspondence Analysis (CCA) based on the correlation between months of sampling, diatoms and physicochemical parameters of Oubeïra Lake. (2) Canonical Correspondence Analysis (CCA) based on the correlation between years, diatoms and physicochemical parameters of Oubeïra Lake. (3) Canonical Correspondence Analysis (CCA) based on the correlation between sampled stations (S1 and S2), diatoms and physicochemical parameters of Oubeïra Lake.

ing conditions to release it in large quantities if the medium becomes reducing (Sehili, 2008). We found low levels of orthophosphate (0–4 µmol l), these low levels are due to the high phytoplankton biomass consumption of this element (Seyni, 2006). The same author has shown that phosphorus is used to describe the degree of fertility of lakes when the concentration is lower. At 0.32 µmol/l the lake is oligotrophic, while it is between 0.32 and 0.68 µmol/l in mesotrophic lakes and greater than 0.97 µmol/l in eutrophic lakes. From these results, Oubeïra Lake is considered oligotrophic in winter and eutrophic in summer. According to our experimental study at Oubeïra Lake, nitrate concentration is very high during the two months of July and January, respectively 40 and 45 µmol/l. The elevation of nitrate at the lake level is caused by agricultural discharges. Thus, the concentration of nitrite reaches 6 µmol/l during July. Our results are very similar to those of Sehili in 2008 in the same study area. The suspended matter at the lake level is very high in spring (March) and summer (July). Our results are very similar to those of Dakki (2003) and Sehili (2008), who explained that the abundant precipitation during the winter and the shallow depth of the lake are at the origin of this rise; abundant rainfall generates floods that contribute to the "fattening" of the lakes by allochthonous inputs. The shallow lake facilitates the transfer of sedimentary particles to the water column by waves created by the wind. As for the summer increase of SS in the lake, it may be related to the high microalgal density observed during this period. We can classify Oubeïra Lake as meso-eutrophic in winter (SM in February = 10mg/l) and hyper-eutrophic (<25 mg/l) in summer. When environmental conditions are favorable, the development of diatoms is at best.

Microscopic observation of the frustules of diatoms sampled at Oubeïra Lake, allowed us to identify 18 genera, dominated by *Cymbella*, and *Navicula*. Sehili (2008) identified 24 genera dominated by *Navicula* and *Fragilaria*. The summer period (August) is the most diverse at Oubeïra Lake; this important diatom population is related to the availability of nutrients, light and especially the high concentration of nitrates. At Oubeïra Lake at the two stations, the average values of the indices is equal to H (2017) = 2.34, H (2018) =2.22. Chaïb et al. (2011) and Chaïb & Tison-Rosebery (2012) reported the dominance of a single species (*Achnanthidium minutissimum*) in the wadi el Kebir in northeastern Algeria, the mean values of the Shannon index is equal to H = 3.7. In northwestern Algeria, Nehar et al. (2015) studied the diatoms of Oued El Hammam and calculated this index as H = 1.9.

In conclusion, Oubeïra Lake is considered meso-eutrophic in winter and hyper-eutrophic in summer, due to its proximity to neighboring farmland using uncontrolled releases of fertilizers. The availability of nutrients at Oubeïra Lake and the surrounding favorable conditions have contributed positively to the richness of the diatom community. The Oubeïra Lake is a protected natural reserve which shelters a very diversified fauna and flora, the alarming state of this lake is due to the traditional agriculture with its irrational use of the fertilizer and thus the intensive irrigation participant to its degradation and lead it towards eutrophication. Permanent monitoring of the water quality of Oubeïra Lake is required, and diatoms can be used as bioindicators of water quality.

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Overview of Pronk's day gecko *Phelsuma pronki* (Seipp, 1994) (Reptilia Gekkonidae) from Mangabe protected area, eastern Madagascar

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ABSTRACT We surveyed Pronk's day gecko *Phelsuma pronki* (Seipp, 1994) (Reptilia Gekkonidae) from three sites within Mangabe protected area. Sites were chosen according to their location and altitude. Fieldwork was done in October-November 2018 when the animal is very active. Thirty transect lines were surveyed, ten for each site. One transect measure 200 m and distance between transects should be 50 m at least to avoid pseudo-replication on transect location. In total, we encountered 31 individuals, 18 of them were found from Analamay forest. The species was found mostly on dead trees from an open area inside of primary forest.

KEY WORDS Conservation; Habitat; Mangabe; *Phelsuma pronki*; Population; size.

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INTRODUCTION

The genus *Phelsuma* Gray, 1825 (Reptilia Gekkonidae) is a group of day geckos with splendid colourations that is mainly distributed on the islands in the western Indian Ocean (Glaw & Rosler, 2015). Madagascar is home of 35 species (Uetz & Hošek, 2014) and some papers indicated that the genus *Phelsum*a probably originated in Madagascar and subsequently dispersed and radiated in the other Indian Ocean archipelagos, with a different colonisation history on each island group (Austin et al., 2004; Harmon et al., 2008; Rocha et al., 2009, 2010). The last red list assessment classified 12 species, and of these about 1/3 of Malagasy *Phelsuma* are threatened and four of them were listed Critically Endangered. Regardless of their IUCN Red List status all Phelsuma species are listed on the CITES Appendix II (Glaw & Rosler, 2015).

Phelsuma pronki (Seipp, 1994) is endemic to Madagascar and occurs in isolated fragments in the eastern rainforest bordering the central highlands of Madagascar, in the Andramasina region, Anjozorobe reserve and in the Ambatovy area. It is one of the Critically Endangered species because of its extent of occurrence is estimated less than 100 km². It only persists in severely fragmented forest habitat, which is still being degraded by human pressures such as habitat loss occurring within this species' range and harvesting for the international pet trade. Populations of this species have declined over the past years (Raxworthy & Vences, 2010). Few individuals of the species were found from Mangabe protected area in 2014 (Bower et al., 2014). This study aims to collect more information on Pronk's day gecko within the protected area such as its distribution, population size and habitat preferences for the benefit of its conservation.

MATERIAL AND METHODS

Field work was done within Mangabe-Ranomena-Sahasarotra reserve which is situated in south-western of Moramanga between Latitude S19°00 and S19°28 and Longitude E48°05 and E48°25 with an altitude range between 800 to 1300 meters (Madagasikara Voakajy, 2015). It is included in the **east** at mid-altitude bioclimatic zone described by **Du Puy & Moat (1996).** The vegetation is dominated by evergreen humid forest characterized by high canopy and closed forest. We selected three camp sites within the protected area which have been chosen according to their biogeography and the altitude range. The first camp was Ampahatra situated in the north of the protected area with low altitude range between 943–990 m. The second camp was Lakambato in the middle with an altitude between 989 to 1039 meters. The last camp was Analamay situated so far in the south with an altitudinal range between 996 to 1089 meters (Fig. 1).

We surveyed Pronk's day gecko along 10 transects of 200 m from each camp site. Transects were installed in different types of habitat such as forest edge, interior of the forest following the top, and degraded area outside of the forest with dead trees. Each transect was visited three times: twice in the morning between 7h00 to 11h30 and once in the afternoon between 13h00 to15h00; towards these hours, the geckos are more active and easier to find. The survey was done by four people composed of one specialist and three trained guides who knew the species and the area of interest. For each observation, we collected data on: animal height from the ground, total tree height, life status of the tree, activity of the animal at its first observation, GPS coordinates. We calculated the kilometric abundance index (KAI) following the formula adapted from Preatoni et al. (2012).

$$\text{KAI} = \frac{\text{Number of presence sightings}}{\text{Transect length covered (m)}} * 1km$$

RESULTS AND DISCUSSIONS

In total, we encountered 31 individuals with 25 observed along transects and 6 incindentally ob-

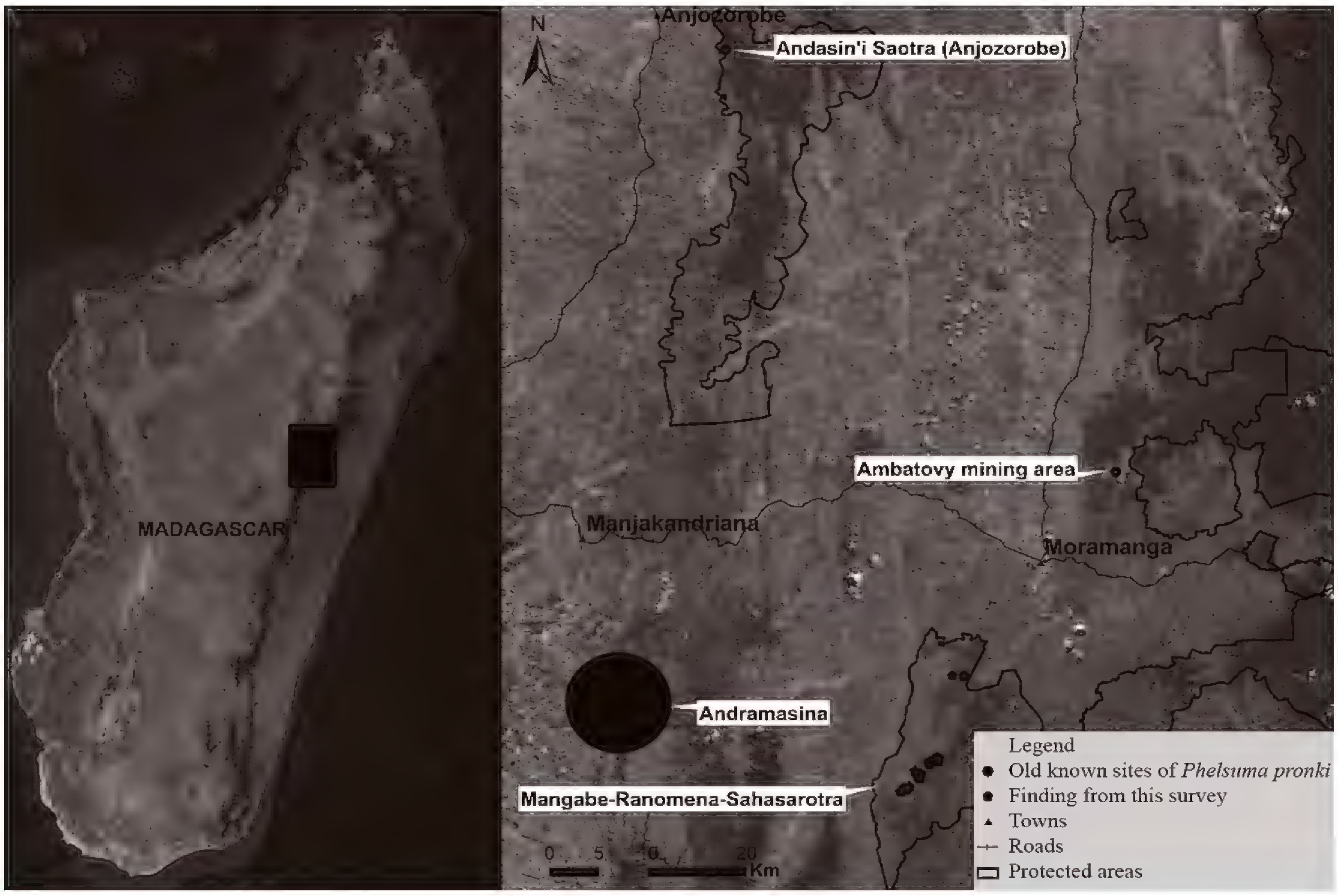
MADAGASCAR
N
Anjozorobe
Andasin'i Saotra (Anjozorobe)
Ambatovy mining area
Manjakandriana
Moramanga
Andramasina
Mangabe-Ranomena-Sahasarotra
0 5 0 20
Km
Legend
● Old known sites of *Phelsuma pronki*
● Finding from this survey
▲ Towns
Roads
Protected areas

Figure 1. Map showing study sites and Pronk's day gecko distribution in Madagascar.

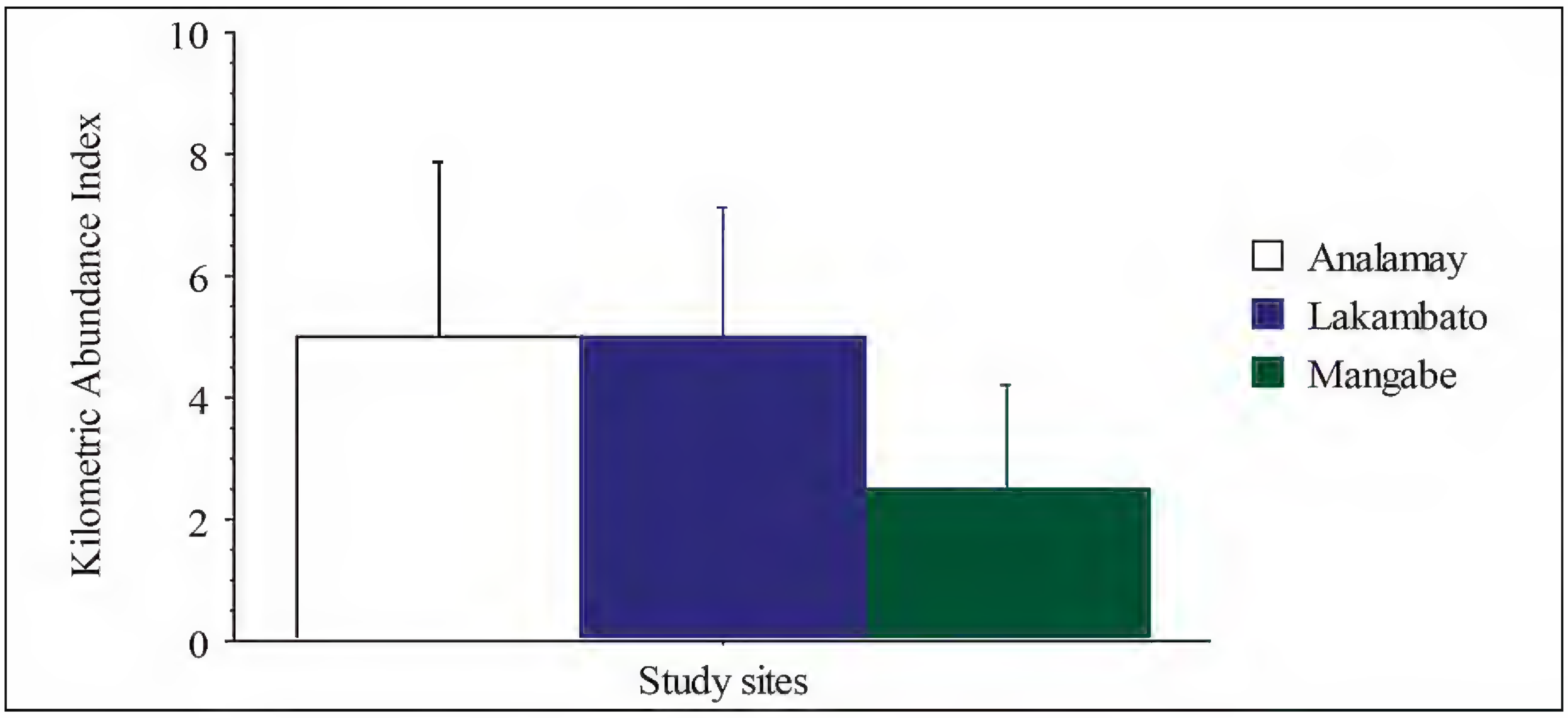

Figure 2. Kilometric abundance index (KAI) per site.

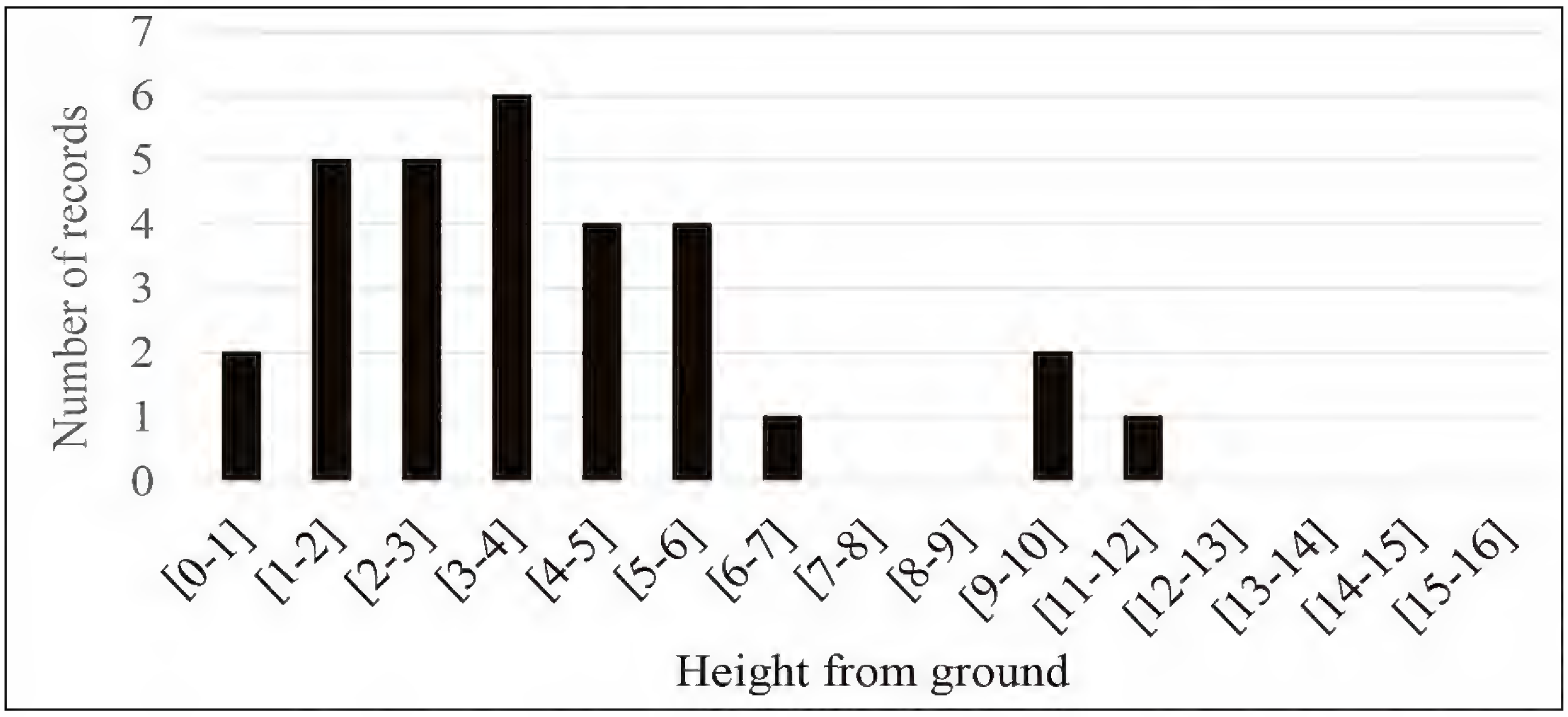

Figure 3. Frequency of roosting height.

served along the road. Abundance index changes between sites, as Analamay and Lakambato had the same abundance of 5 ind.km-1, in contrary to Ampahatra site with 2.5 ind.km-1 (Fig. 2). However, this difference is not significant (p-value=0.53). All the six incidental observations were found in Analamay forest. Twenty-eight of the individuals were adult and we found gravid female during the survey. Pronk's day gecko was found mostly in dead tree but we found two individuals on living trees one in Ankolokoloka forest in Lakambato site and the other one from Analamay. Most individuals were observed by themselves, with the exception of four cases in which two couples were found in one tree in Analamay and Lakambato. This study confirms the presence of Pronk's day gecko within Mangabe protected area situated about 30 km east of Andramasina and can be considered as a range extension in addition to its actual range during its conservation status assessment. This site is actually protected but threats still exist there which can affect the species such as slash-and-burn agriculture and illegal collection. Despite

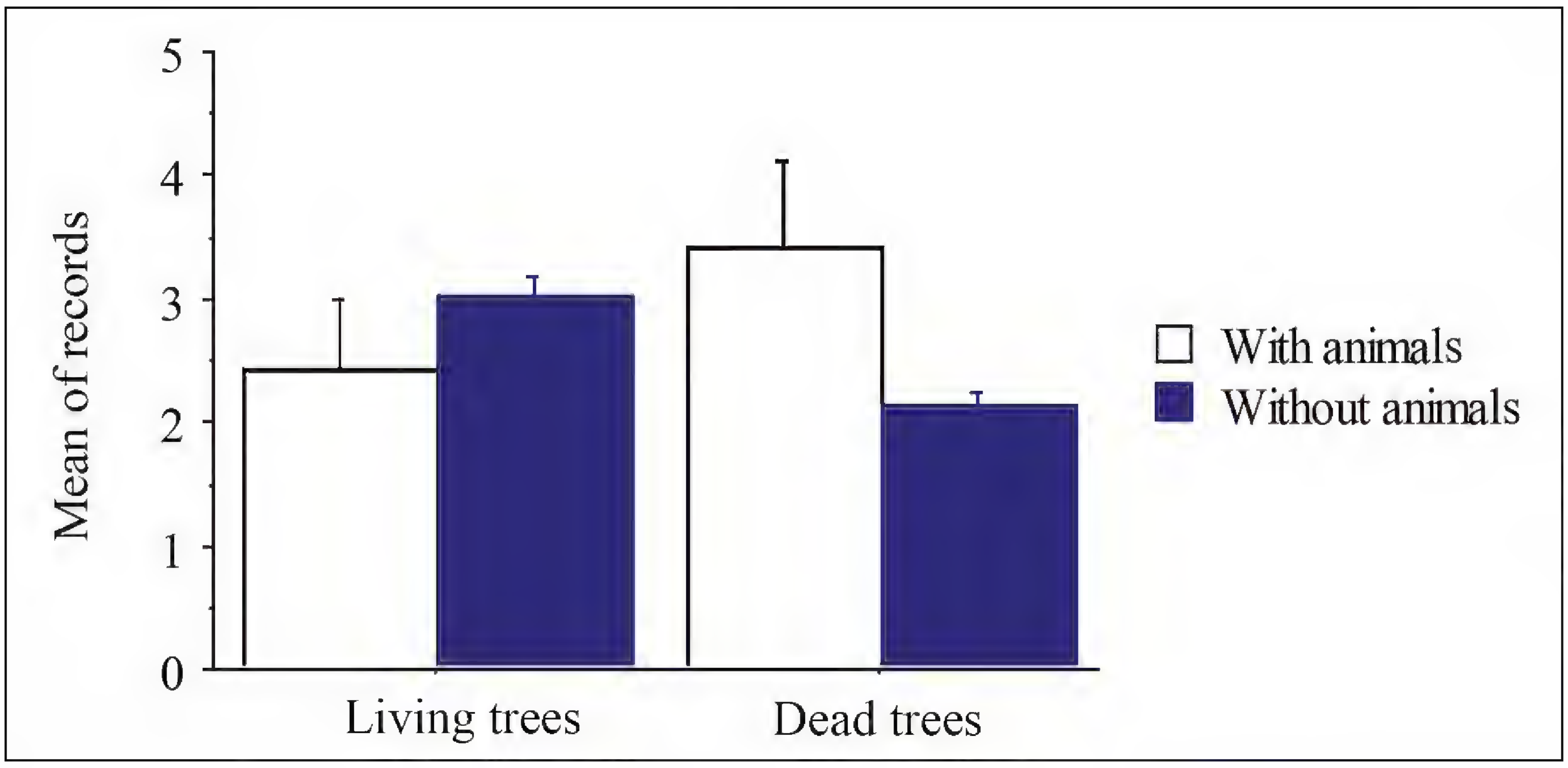

Figure 4. Number of dead and living trees from the areas with and without animals.

this range extension, the species still under threat can be considered as Critically Endangered according to A1 criteria (IUCN, 2001. A: population size reduction; 1: if the reasons for population reduction no longer occur and can be reserved, the population needs to have been reduced by al least 90%).

The species was found from 0.5 to ten meters above ground, with 24 of them between one to six meters (Fig. 3). *Phelsuma pronki* prefers big dead trees easily exposed to the sun early in the morning and late in the afternoon. They were all found on the main trunk in the middle of the tree. At their first observation, only four individual were actively running or searching food.

During this survey, we found the animal from areas where dead trees were abundant but with less disturbance (Fig. 4). All individuals were observed on trees which confirm Seipp's statement that the species is arboreal and is known to be from humid rainforests (Seipp, 1994). Most of the individuals were found on dead trees, in accordance also with Raxworthy & Vences' (2010) statement that the species appears to live mainly on dead trees within rainforest.

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New records of *Biuve fulvipunctata* (Baba, 1938) (Gastropoda Cephalaspidea) and *Taringa tritorquis* Ortea, Perez et Llera, 1982 (Gastropoda Nudibranchia) in the Ionian coasts of Sicily, Mediterranean Sea

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ABSTRACT In the present paper, two sea slug species, *Biuve fulvipunctata* (Baba, 1938) (Gastropoda Cephalaspidea) and *Taringa tritorquis* Ortea, Perez & Llera, 1982 (Gastropoda Nudibranchia), are reported for the second time in the Ionian coasts of Sicily (Italy). *Biuve fulvipunctata* is an Indo-West Pacific cefalaspidean, previously reported for Italian territorial waters only in Faro Lake (Messina, Sicily). *Taringa tritorquis* is a species originally described for Canary Islands and hitherto found in Sicily and probably in Madeira. Both species are easily identifiable for their characteristic external morphology. Indeed, *B. fulvipunctata* shows a W-shaped pattern of white pigment on the head, while *T. tritorquis* presents rhinophore and gill sheaths with spiculous tubercles crown-shaped and an orange-yellowish body coloring. Since *B. fulvipuctata* has been previously reported in Faro Lake, probably, the specimen reported in this note could have been taken in veliger stage through the Strait of Messina currents. Otherwise, the veliger has been carried attached to the keel of boats. Instead, it is still unclear if *T. tritorquis* could be a native or non-indigenous species of the Mediterranean Sea. Indeed, due to its small size and its sciaphilous behavior, it might be a rare species, overlooked until now.

KEY WORDS Aglajidae; *Biuve fulvipunctata*; Discodorididae; Ionian Sea; Sicily; *Taringa tritorquis*.

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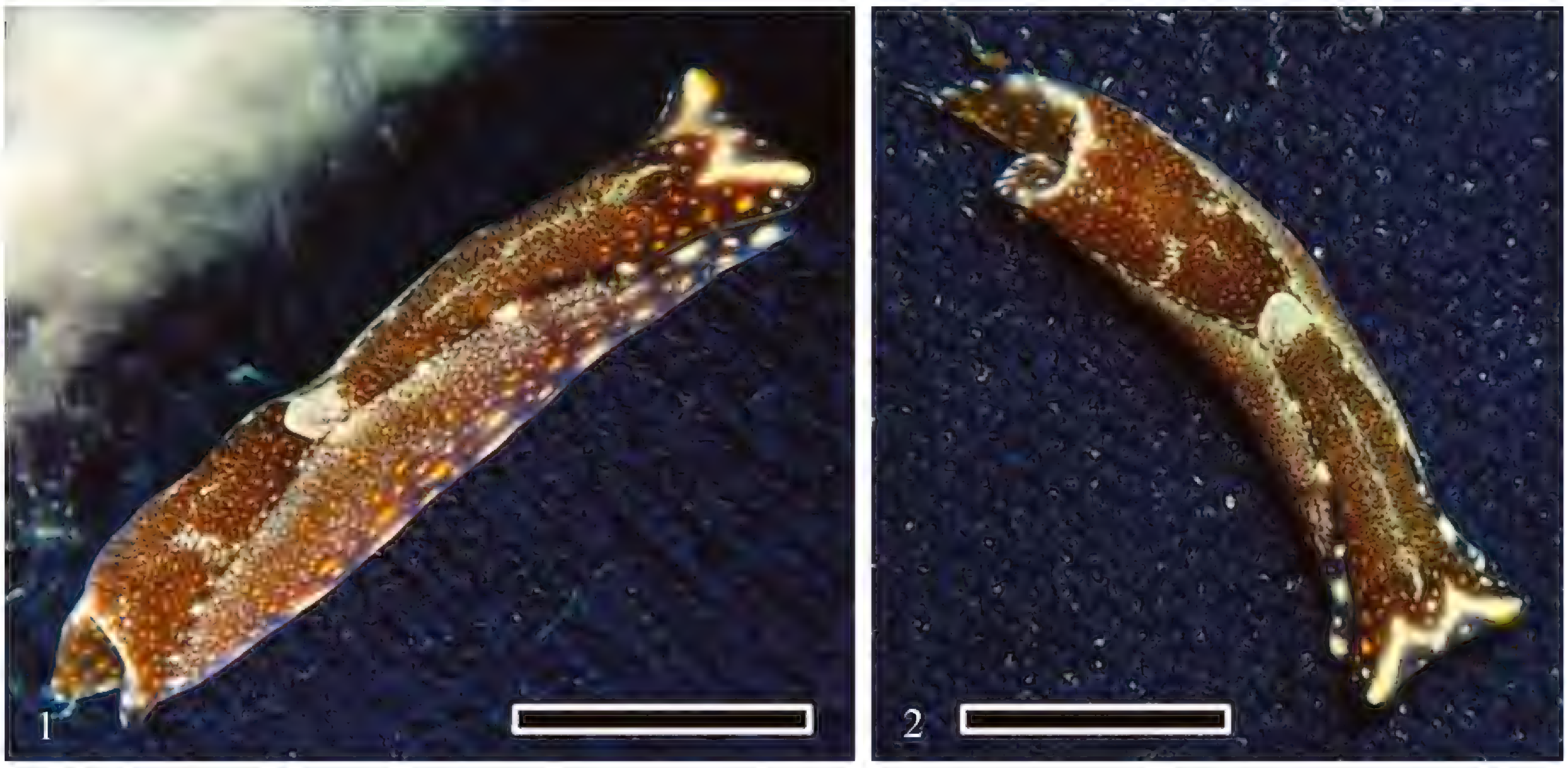
INTRODUCTION

Recently, two new sea slugs have been found along the central-eastern coast of Sicily. One of them, *Biuve fulvipunctata* (Baba, 1938) is an Indo-West Pacific cephalaspidean of the family Aglajidae Pilsbry, 1895 (1847) (Malaquias et al., 2016; Kousteni et al., 2019), while the other, *Taringa tritorquis* Ortea, Perez et Llera, 1982 is a rare nudibranch of the family Discodorididae Bergh, 1891.

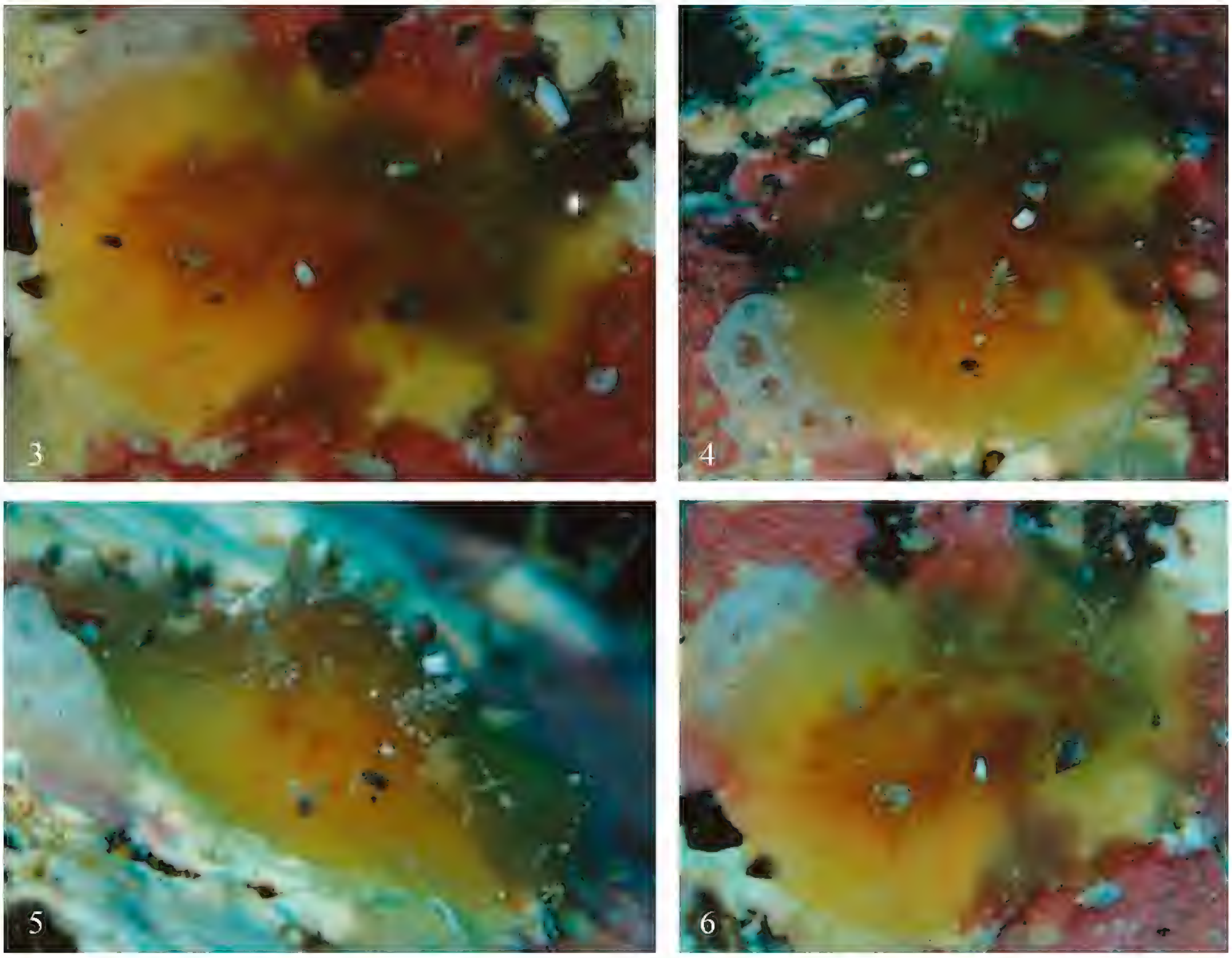
Biuve fulvipunctata was reported for the first time in the Mediterranean Sea as *Chelidonura mediterranea* Swennen, 1961 in 1959, in Antalaya bay (Turkey) (Swennen, 1961). Then, *C. mediterranea* was considered as a junior synonym of *C. fulvipunctata* (Gosliner, 1980; Malaquias et al., 2016). Today, *C. fulvipunctata* has been attributed to the genus *Biuve* Zamora-Silva et Malaquias, 2017 (see Zamora-Silva et al., 2018). In this taxon the external colouring is very variable, with a range from blue with orange/yellow spots and few white patches to light/dark brown with small white dots. Nevertheless, this species always shows a distinctive W-shaped pattern of white pigment on the head (Zenetos et al., 2004; Kousteni et al., 2019). After the first report in 1959, this species had spread in great part of the Mediterranean Sea, reaching these following localities: Israel in 1986 (Mienis & Gat, 1987), Maltese islands in 1993 (Perrone & Sammut, 1997; Sammut & Perrone,1998), Cyprus in 2003, 2006 (Tsiakkiros & Zenetos, 2011), and 2015 (Malaquias et al., 2016), France in 2014 (Horst, 2015), Balearic islands (Spain) in 2015 (Karachle et al., 2016), Sicily (Italy) in 2015 (Malaquias et al., 2016) and Croatia in 2018 (Kousteni et al., 2019). Moreover, since this species has been found in the Red Sea only twice (Galil et al., 2016), Malaquias et al. (2016) hypothesized that *B. fulvipunctata* entered the Red Sea through the Mediterranean Sea. After that, Galil et al. (2016) have questioned the veracity of this hypothesis. However, to date, the dispersal path of this species is still unknown.

Taringa tritorquis was described by Ortea et al. (1982) based on the finding of three specimens at a depth of 3 m in Lanzarote (Canary Islands). In the original description, it was highlighted a difference in the coloring of specimens with different sizes: individuals of 6 mm have a red-violet body, darker in the middle part and pinker towards the edges of the mantle, while the smaller specimens, of 4-5 mm, are pinkish-yellow with a darker visceral zone. In all specimens on the notum, there are numerous dark maroon spots with an irregular distribution. Moreover, the notum presents spaced tubercles which have the same shape and color on all the back. The gill is formed by six uni-bipinnate white leaves with red spots. The leaves have a wide triangular rachis and the edge of the rhinophore and gill sheaths have white, spiculous tubercles crown-shaped. Rhinophore sheaths have 6-8 tubercles of this type, while gill sheath has 10 ones. Rhinophores are yellowish-white, with whitish lamellae and some dark spots. Finally, rhinophores have a heart-shaped section, with an anterior groove. Therefore, according to Ortea et al. (1982), this species differs for its distinct external morphology, due to the presence of characteristic tubercles in the rhinophore and the gill sheaths and for the coloring. The first report of *T. tritorquis* in the Mediterranean Sea was based on the finding of two specimens in a station called Santa Maria La Scala, located along the Ionian coast of Sicily (Lombardo & Marletta in Gerovasileiou et al., 2020).

The aim of this paper is to report the second record of *B. fulvipunctata* for the Ionian coasts of Sicily and the second record of *T. tritorquis* for the whole Mediterranean basin. Additional data on these two species are provided.



Figures 1, 2. *Biuve fulvipunctata* from Santa Tecla (Ionian Sea, Italy).
Fig. 2: dorsal view. Scale bars: 5 mm. (photos A. Lombardo)



Figures 3-6. *Taringa tritorquis* found in Ognina (Ionian Sea). Fig. 3: dorsal view of the specimen. Fig. 4: antero-dorsal view of the specimen. Fig. 5: front view of the specimen Fig. 6: dorsal view of the specimen showing slight white lines arranged transversally (photos A. Lombardo)

MATERIAL AND METHODS

The *B. fulvipuctata* specimen was found in a station called Santa Tecla (37.639923 N, 15.184157 E) in the municipality of Acireale, while the *T. tritorquis* specimen was observed in a station called Ognina (37°31’51.7152” N, 15°7’10.5672” E), in the municipality of Catania. Both sites are located along the central-eastern coast of Sicily (Italy). Santa Tecla is a fishing town, which hosts a small touristic port. In particular, the specimen was found in an area near the harbour. Instead, Ognina is a strongly anthropized site, because of the coastal overexploitation, due to the presence of a harbour and a large number of apartment buildings. Geologically, the whole sector is characterized by subvolcanic rocks: columnar basalts and effusive submarine products forming fields of pillow lavas (Sciuto et al., 2017). Both specimens were identified in vivo and photographed by an Olympus TG-4 Underwater Camera during two different scuba dives conducted by the authors.

RESULTS

On 27th July 2019, a specimen of *B. fulvipunctata* (Figs. 1, 2) was found at a depth of 4.4 m on a thallus of *Padina pavonica* (Linnaeus) Thivy. The specimen was 1.5 cm long and it had a dark blue body colouring with yellowish-orange spots scattered on the surface. On the anterior part of the cephalic shield, it presented a large white W-shaped sign with a yellow edging, which is a diagnostic feature of this species (Swennen, 1961; Malaquias et al., 2016; Kousteni et al., 2019). On the cephalic shield there was also a white stripe, formed by numerous white dots, in an anterior-posterior direction. The posterior apex of the cephalic shield showed a lot of such points, appearing completely white. Moreover, these white dots were present also along the upper flank of parapods and formed two small transverse stripes on the surface of the visceral hump. The edges of parapods and the posterior limit of the visceral hump presented a row of greater conspicuous white dots. Instead, the *T. tritorquis* specimen (Figs. 3–6) was found on 29th February 2020 at a depth of 6.9 m, under a stone covered by sponges. The specimen was about 8 mm long and had an orange-yellowish body, with the middle part of the notum darker than the marginal parts. On the notum there were orange-brownish patches irregularly distributed mostly in the middle part and dots of the same coloring distributed on all the surface. Both gill and rhinophores were white with maroon spots. Rhinophores had a heart-shaped section. The edge of notum presented bright white dots. The edge of rhinophore and gill sheaths had white spiculous tubercles with a crown shaped. On the notum, there were slight white lines resembling scars, most of which transversely arranged. Therefore, this specimen perfectly corresponds to the first specimen found in Santa Maria La Scala and depicted by Lombardo & Marletta (Gerovasileiou et al., 2020: Fig. 1A). The only difference between these individuals is that the specimen of Santa Maria La Scala presented the slight white lines resembling scars arranged longitudinally.

DISCUSSION

This short note reports the second record of *B. fulvipunctata* in Sicily, after that of Faro Lake (Messina) (Malaquias et al., 2016) and the second record of *T. tritorquis* in the Mediterranean Sea. A case similar to that of *B. fulvipunctata* occurred for another species, *Godiva quadricolor* (Barnard, 1927), a nudibranch of the family Facelinidae Bergh, 1889. In fact, this latter species was found in Faro Lake with stable populations (Furfaro et al., 2018) and then was seen in 2018 in Santa Maria La Scala (Lombardo & Marletta, 2019), a station located near Santa Tecla. Even for *B. fulvipunctata*, many adults' specimens were observed in Faro Lake with established populations (Malaquias et al., 2016). Therefore, as hypothesized by Lombardo and Marletta (2019) for *G. quadricolor*, the *B. fulvipunctata* specimen could have been carried in veliger stage through the Strait of Messina currents. Another hypothesis could be that the veliger of this species has travelled attached to the keel of some boats and has been brought directly in Santa Tecla.

Instead, the actual distribution of *T. tritorquis* includes Canary Islands, Sicily and probably Madeira (Lombardo & Marletta in Gerovasileiou et al., 2020). Since in Sicily three specimens have been observed throughout three years (from 2018 to 2020), it could be hypothesized that *T. tritorquis* has settled in this area. However, since this species was documented only twice in the Mediterranean Sea (Lombardo & Marletta in Gerovasileiou et al., 2020; present work), there are not enough data to define if *T. tritorquis* is a native or non-indigenous species. Indeed, because of its small size and cryptic behavior, this species is not easy to detect and probably is rare and has been overlooked until now.

Overall, through the present data and the previous observations (Ortea et al., 1982; Lombardo & Marletta in Gerovasileiou et al., 2020), it was checked that *T. tritorquis* is a sciaphilous species that lives in shallow waters (within 10 m), among algae or under the stones probably feeding on sponges, as other species of the genus *Taringa* (Perrone, 1985).

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Species diversity of Spiders (Araneae) in Mimbilisan Protected Landscape, Misamis Oriental, Philippines

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ABSTRACT Spiders have a potential role as bioindicator of ecological health. Yet, little is known about them especially in forested areas of the Philippines. This study determined the species diversity of spiders in three different sampling sites established in Mt. Mimbilisan Protected Landscape. A combination of beat-netting and vial-tapping methods was used to collect samples. One hundred eight species of spiders belonging to 17 families were recorded. Fifteen species are a new record to the Philippines. Highest species richness and abundance were observed in the riparian forest (Site 2) and lowest in the mixed dipterocarp forest (Site 1). Salticidae is the spider family with the highest species richness and abundance. *Opadometa fastigata* of family Tetragnithidae was the most abundant species. A great number of adult spiders (82.42%), which were mostly females (88.00%), was documented. Even distribution (E=0.7676) was recorded in the whole study area. Leaf surfaces and branches or stem of plants were the most recurring microhabitat types of spiders. The spiders were found to belong to seven guilds with the orb weavers as the most dominant guild (37%). The highest diversity was recorded in Site 2 (H'=3.781). Results indicate high spider diversity in Mt. Mimbilisan which highlights the conservation importance of the protected landscape.

KEY WORDS Araneidae; conservation; forest; orb-weavers; Salticidae.

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INTRODUCTION

Spiders belong to a special group of invertebrates comprising the largest order Araneae. They are sensitive to environmental changes and influence neighboring populations. They are abundant and diverse in nature (Wilder, 2011). They encompass the class Arachnida that utilizes a wide range of niches (Puja, 2014). Spiders are a mega-diverse group comprising 47,445 described species (World Spider Catalog, 2018) and are considered as the seventh most diverse order worldwide (Cardoso, 2012). They can be found all around except in air and water (Foelix, 2011), from trees, under stones and logs, in garbage, and on the forest floor (Mathew et al., 2009).

Spiders are considered as an important group from both an economic standpoint in their use as biological control agent and in their diversity and adaptation to a number of differing habitats (Mahalakshmi & Jeyaparuathi, 2014). They respond rapidly to alterations in environment and thus, used as indicators of ecological change (Hodge & Vink, 2010). They serve as limiting factors in the increase of pest populations in different ecosystems through their predatory behavior (Sharma, 2014). Spider silk nowadays is used to make bullet proof vest, parachutes, surgical threads, artificial tendons, and even biodegradable bottles (Hinman et al., 2003). Venom of spiders is being studied in the field of medicine (Clarke, 2002).

According to Chen & Tso (2004), a lot of scientific studies on spiders were conducted in temperate regions while tropical areas have relatively less investigation. Species richness and their relative abundance help in describing spider communities (Sorensen et al., 2002). Without being affected by their high diversity and ubiquity, large quantities of species have restricted distribution and biogeographic patterns of assemblages (Carvalho et al., 2011). Royauté & Buddle (2012) reported that in agricultural fields, there are evidences that synchronization with habitat changes and disturbances are present in species that are dominant. Areas near or with human settlements in Brazil have higher spider diversity indices and evenness values when compared to undisturbed areas (Freitas et al., 2013). Environment alterations may affect their distribution and assemblages by variations of plant community structure, disturbance, and abiotic factors (Juario et al., 2016). According to Hore & Uniyal (2009), spiders are utilized as bioindicators for evaluating the impact of anthropogenic disturbances on natural ecosystems. They face an exceptionally high risk of extinction (Thomas et al., 2004) caused by human disturbance and climate change.

The Philippines, a tropical country, is among the 17 mega diverse countries which constitutes 70-80% of the world's biodiversity. For many parts of the Philippines, little is known of the arthropod fauna. One of the most diverse groups of organisms in the Philippines is the spiders (Wankhade et al., 2012) consisting of about 517 species belonging to 225 genera and 38 families. Studies on spiders in the country are limited only to agricultural areas, particularly rice fields, but they have the highest record in all of Asia's tropical rice fields (Workman, 1896; Barrion & Litsinger, 1995; Barrion, 2001). In Mindanao, the second largest island in the Philippines, recent studies on spiders were reported in Pulacan falls, Zamboanga del Sur (Dacanay et al., 2014), Mt. Matutum, South Cotabato (Garciano et al., 2014), Mt. Pinukis, Zamboanga del Sur (Lalisan et al., 2015), Marilog District, Davao City (Patiño et al., 2016), Sacred Mountain in Marawi City (Juario et al., 2016), Imbayao, Bukidnon (Mondejar & Nuñeza, 2016), and caves in Mindanao (Enriquez & Nuñeza, 2014).

Of the remaining forest in the country, 26% can only be found in protected areas (Ong, 2002). Mimbilisan Protected Landscape is among the 240 protected landscape areas of the Philippines. However, there is no spider fauna data in this protected landscape and thus, this research is significant as this will provide baseline data of spider fauna and will indicate the present ecological health status of Mimbilisan Protected Landscape. It will also contribute to the existing studies on spiders in the Philippines especially on the island of Mindanao. The study aimed to determine species diversity, guild structure, and microhabitats of spiders in Mimbilisan Protected Landscape.

MATERIAL AND METHODS

Study area

Based on the IUCN Protected Area Management Category System, Mimbilisan Protected Landscape (Figs. 1-3) belongs to Category 5, areas that are managed for landscape conservation or recreation. It serves as a watershed that provides water to its nearby communities. It is composed of mixed dipterocarp forest that covers 66.515 hectares in Brgy. Mapua, municipality of Balingaoan, Misamis Oriental. Mimbilisan Protected Landscape is located at 8.94617 latitude; 124.8676 longitude. The Mindocdocan Creek can be found at its base. In some areas outside of the protected area, agricultural activity was observed.

Sampling sites

Three sites in Mimbilisan Protected Landscape were sampled for 10 days for a total of 186 work hours. The sampling sites were selected based on the following criteria: accessibility, habitat structure, degree of exposure to human activities, and geographical position. Disturbances in the sampling sites were qualitatively categorized as low, intermediate, or high based on the accessibility, presence of facilities, and presence of human dis-

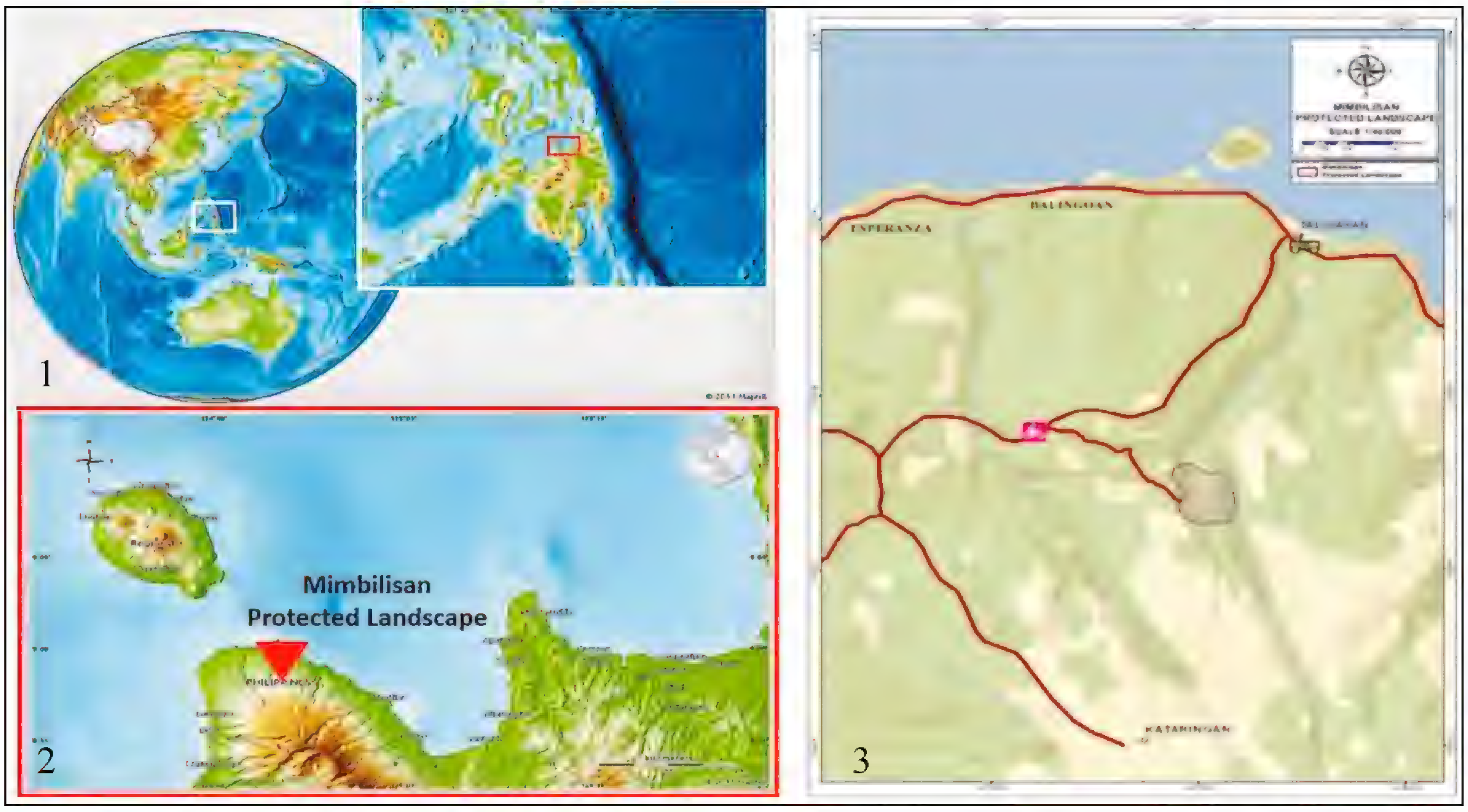

Figure 1. Map of Australasia and central-southern Philippines (Maphill, 2018). Figure 2. Map of northern Mindanao (Maphill, 2018). Figure 3. Location of the study area (BMB-DENR, 2015).

turbance. Transect lines were established along trails due to the gorge shape of the mountain.

Sampling site 1 is a mixed dipterocarp forest with coordinates of 8°56.820'N, 124°52.042'E. Its elevation ranges from 415–465 meters above sea level. The site has a mountainous slope and secondary vegetation type. Sunlight cannot easily penetrate through the ground due to the presence of high density of emergent and canopy trees. Emergent trees were *Shorea* sp. whereas canopy trees include *Shorea negrosensis*, *S. contorta*, *Pterocarpus indicus*, *Swietenia mahogany*, *Dracontomelon dao*, *Artocarpus sericicarpus*, and *Ficus gul*. Understory plants include the family Arecaceae, *Costus igneus*, and *Caryota mitis*. Most of the ground cover plants were *Schismatoglottis calyptrat*a and ferns. Leaf litter depth measures about 2 cm. The covering canopy trees have epiphytes such as ferns and vines coiling in their trunks. Orchids were also observed. Site 1 has a clay soil where exposed rocks and few fallen logs were present which may have been caused by a storm. A freshwater stream was located 100 m away. Its distance to anthropogenic clearing was 450 m. Rubber plantation was near the area. Site 1 is where the main access is located which serves as the initial pathway in accessing the freshwater stream and thus high disturbance, mainly human-made, can be observed in the site.

Sampling site 2 is a riparian forest with coordinates of 8°56.834' N and 124°52.124' E. Its elevation ranged from 350–450 m a.s.l. The site has an undulating slope and covered with secondary vegetation. A freshwater stream with shallow pools of water serves as a faunal corridor, connecting Sites 1 and 3. The site was dry, revealing large rocks due to the diversion of water for the water system of the people in the locality. Rocks were mainly covered with *Bryophyta* sp., especially near pools of water. The emergent tree was *Shorea* sp. while canopy trees were *Dracontomelon dao*, *Bosscheria minahassae*, and *Artocarpus odoratissimus*. The canopy epiphytes present include moss, vines, and ferns. Fruit-bearing tree taxa include *Lansium parasiticum*, *Averrhoa carambola*, and *Artocarpus odoratissimus*. Ferns, grasses, and sedges were rarely observed. Other plants include bamboo, *Ficus benjamina*, *Pandanus yvanii*, *Cheilocostus speciosus*, *Poikilospermum suaveolens*, *Clerodendrum paniculatum*, *Alocasia princeps*, and *Aglaonema nitidum*. Presence of *Musa* sp. was also noted. Forest floor near the stream is characterized by leaf litter, abundance of exposed rocks, humus, mosses, ferns, and fallen logs. Its distance to the anthropogenic clearing was about 500 m. Intermediate disturbance was observed as indicated by the presence of plastic waste within the boundary of the freshwater stream. On-site disturbance also includes natural tree-fall.

Sampling site 3 is a mixed dipterocarp forest with neighboring agroecosystem. It has coordinates of 8°56.913'N, 124°52.109'E with elevation of 430-485 meters above sea level. The site has mountainous slope and secondary vegetation type. The emergent tree was *Shorea* sp. while canopy trees include *Shorea negrosensis*, *S. contorta*, *S. polysperma*, *Dipterocarpus validus*, and *Ficus benjamina*. Understory plants in the area include *Diplodiscus paniculatus*, family Arecaceae, *Daemonorops ochrolepis*, *Calamus caryota*, and *Calamus mitis*. Neighboring agroecosystem is partly used for growing coconuts, *Cocos nucifera* and coffee, *Coffea* sp. Forest floor is covered with moderate leaf litter measured to be about 1 centimeter in depth and few exposed rocks and fallen logs which are common microhabitats of ground-dwelling spiders. Ground was wet, covered with plants like mosses, ferns, and *Schismatoglottis calyptrata*, the dominant ground cover plants present in this site. The distance of the site to anthropogenic clearing was about 1 km. Site disturbances were human-made and natural tree-fall. Huge water pipes that extend to the community area for water source were present. Compared to Site 1, Site 3 is difficult to access due to the presence of enormous vegetation so very few anthropogenic disturbances were observed and thus it has low disturbance.

Collection, processing, identification of samples, and analysis

Sampling was conducted on July 18–27 2018 for 10 field days for a total of 186 work hours. Sampling starts every morning from 900 hours to 1300 hours, in the afternoon from 1400 hours to 1600 hours, and evening from 1800 hours to 2100 hours. Different sampling areas with different habitat structure, disturbance level, accessibility, and geographical position were established within the transect line. Collection in every point was extended up to 10 meters (m) to the left and 10 m to the right of the transect line. For arboreal spiders, leaves, bushes, tree trunks, ferns, and grass lands were explored. Microhabitats of spiders such as fallen logs and leaf litter were examined for ground-dwelling spiders. Beat-netting and vial tapping methods were done to collect samples. Captured samples were placed in plastic cups and plastic bags to prevent escape of the motile spiders. Samples were then photographed. Voucher specimens were placed in vials with 90% ethanol. World Spider Catalog (WSC) created by world renowned arachnologist, Norman Platnick, and hosted by Natural History Museum of Bern was used to determine the general geographic region that a spider species is known to be distributed. For the spiders of the Philippines, the website insectoid.info and some published papers were used. Collection date, compartment name, and habitat were recorded on each vial. Specimens were identified by the third author.

Biodiversity indices which include species richness, relative abundance, Shanon-Weiner Diversity Index, and Pielou's evenness were calculated using Paleontological Statistics Software Package version 3.16.

RESULTS AND DISCUSSION

Species Composition

A total of 108 species belonging to 17 families under 96 genera were collected during the sampling period in different sampling sites (Table 1). This number is higher compared to other areas in Mindanao, Philippines such as spiders recorded in Mt. Matutum, South Cotabato (Garciano et al., 2014) with 23 species under 19 genera and nine families; Mt. Pinukis, Zamboanga del Sur (Lalisan et al., 2015) with 99 species, 16 families, and 64 genera; and in Sacred Mountain in Marawi City (Juario et al., 2016) with 43 species belonging to 11 families under 31 genera. However, the present record is relatively low compared to the spider fauna in Marilog District, Davao City (Patiño et al., 2016) which consists of 171 species under 25 families. Species richness is significantly affected by flooding and vegetation cover within the surrounding areas (Galle & Schweger, 2014). Rocha-Filho & Rinaldi (2011) reported that different vegetation types with varying microhabitat structures affect spider distribution. Site 1 had 44 individuals. Site 2 had the

SPIDERS FAMILY AND SPECIES	SITE 1	SITE 2	SITE 3	TOTAL	RA (%)
ARANEIDAE (True Orb weavers)					
Anepsion depressum (Thorell, 1877)^	**0**	**0**	**1♀**	**1**	**0.549**
Anepsion roeweri (Chrysanthus, 1961)	**1♀**	**0**	**0**	**1**	**0.549**
Anepsion sp.	**1♂SA**	**0**	**0**	**1**	**0.549**
Araneus sp.	**0**	**0**	**1♀**	**1**	**0.549**
Argiope aemula (Walckenaer, 1841)	**0**	**0**	**1i♀**	**1**	**0.549**
Cyclosa sp. 1	**0**	**1♀**	**0**	**1**	**0.549**
Cyclosa sp. 2	**0**	**0**	**2♀**	**2**	**1.099**
Cyrtophora sp.	**0**	**2♀**	**0**	**2**	**1.099**
Eriovixia laglaizei (Simon, 1877)	**1♀**	**1♀**	**0**	**2**	**1.099**
Eriovixia cf. laglaizei (Simon, 1877)	**1**	**1**	**1♀**	**3**	**1.648**
Eriovixia sp. 1	**0**	**0**	**2♀**	**2**	**1.10**
Eriovixia sp. 2	**0**	**1♀**	**0**	**1**	**0.549**
Gasteracantha doriae (Simon, 1877)	**0**	**2♀**	**1♀**	**3**	**1.648**
Hyposinga sp.	**0**	**0**	**1♀**	**1**	**0.549**
Neoscona nautica (L. Koch, 1875)	**0**	**1♀**	**0**	**1**	**0.549**
Neoscona cf. nautica (L. Koch, 1875)	**0**	**1i**	**0**	**1**	**0.54**
Neoscona punctigera (Doleschal, 1857)	**0**	**0**	**1♀**	**1**	**0.549**
Neoscona sp.	**0**	**1♀**	**0**	**1**	**0.549**
Poltys sp.	**0**	**0**	**1i♀**	**1**	**0.549**
Singa sp.	**0**	**0**	**1♀**	**1**	**0.549**
Thelacantha brevispina (Doleschall, 1857)	**1♀**	**0**	**0**	**1**	**0.549**
Verrucosa sp.	**0**	**1i,2♀**	**1♀**	**4**	**2.198**
CLUBIONIDAE (Sac spiders)					
Clubiona biembolata (Deeleman-Reinhold, 2001)^	**1♂SA**	**0**	**0**	**1**	**0.549**
Clubiona corticalis (Walckenaer, 1802)^	**1♀SA**	**0**	**0**	**1**	**0.549**
Clubiona cf. *japonicola* (Bösenberg et Strand, 1906)	**0**	**1♀**	**0**	**1**	**0.549**
Clubiona sp.	**0**	**1i**	**0**	**1**	**0.549**
Clubionidae immature	**0**	**1♀**	**0**	**1**	**0.549**
Nusatidia camouflata (Deeleman-Reinhold, 2001)^	**1♀**	**1♀**	**0**	**2**	**1.099**
Pristidia cf. longistila (Deeleman-Reinhold, 2001)	**0**	**1♀**	**0**	**1**	**0.549**
CTENIDAE (Wandering spiders)					
Ctenus sarawakensis (F.O. Pickard-Cambridge, 1897)	**2♂**	**2♀**	**1♀**	**5**	**2.747**

SPIDERS FAMILY AND SPECIES	SITE 1	SITE 2	SITE 3	TOTAL	RA (%)
Ctenus sp.	0	0	1♀	1	0.549
DEINOPIDAE (Net-casting/Ogre face Spiders)					
Deinopis sp.	1♀	0	0	1	0.549
EUTICHURIDAE (Dark Sac Spiders)					
Cheiracanthium sp.	0	1♀	0	1	0.549
LINYPHIIDAE (Sheet web weavers)					
Plectembolus sp.	0	1♀	0	1	0.549
NEPHILIDAE (Golden Silk Orb-weavers)					
Nephiladae immature	0	0	1i	1	0.549
Nephila pilipes (Fabricius, 1793)	0	2♀i,3♀SA	0	5	2.747
Herrenia sp.	0	1♀SA	0	1	0.549
OXYOPIDAE (Lynx Spiders)					
Hamadruas cf. hieroplyphica (Thorell, 1887)	1♀	0	0	1	0.549
Oxyopes lineatipes (C.L. Koch, 1847)	0	0	1♂	1	0.549
PHOLCIDAE (Cellar spider/daddy long legs)					
Calapnita deelemanae (Huber, 2011)	1♀	0	0	1	0.549
Calapnita subphyllicola (Deeleman-Reinhold, 1986)*	1♂	0	2♀	3	1.648
Pholcus sp. 1	1♀	0	0	1	0.549
PISAURIDAE (Nursery web spider)					
Hygropoda sp.	0	1♂	0	1	0.549
PSECHRIDAE (Lace-sheet weavers)					
Psechrus sp.	1♂,1♀	1♀	1i,3♀	7	3.846
SALTICIDAE (Jumping spider)					
Bavia aericeps (Simon 1877)	0	0	1♀	1	0.549
Bavia sexpunctata (Doleschall 1859)	1♀	0	1♀	2	1.099
Burmattus pococki (Thorell 1895)^	1♀	0	0	1	0.559
Cosmophasis sp. 1	1♂	0	1♀	2	1.099
Cosmophasis sp. 2	0	0	1♀	1	0.549
Evarcha sp.	0	0	1♂	1	0.549
Epeus sp.	1♀	0	0	1	0.549
Hasarius adansoni (Audouin 1826)	0	0	1♂	1	0.549
Myrmarachne malayana (Edmunds et Proszynski 2003)^	0	2♂	1♂,1♀	4	2.198
Myrmaplata plataleoides (O. Pickard-Cambridge 1869)^	0	1♀	2♀	3	1.648
Omoedus sp.	1♀	0	0	1	0.549

SPIDERS FAMILY AND SPECIES	SITE 1	SITE 2	SITE 3	TOTAL	RA (%)
Phintella versicolor (C.L. Koch 1846)^	**0**	**1♂,2♀**	**0**	**3**	**1.648**
Plexippus paykulli (Audoiun 1826)	**1♀**	**0**	**1♂,1♀**	**3**	**1.648**
Portia sp.	**0**	**1♂**	**0**	**1**	**0.549**
Pristobaeus jocosus (Simon 1902)^	**0**	**1♀**	**0**	**1**	**0.549**
Pseudeuophrys sp.	**0**	**0**	**1♀**	**1**	**0.549**
Salticidae immature	**0**	**0**	**1i**	**1**	**0.549**
Telamonia dimidiata (Simon 1899)^	**0**	**0**	**2♀**	**2**	**1.099**
Telamonia cf. *festiva* (Thorell 1887)	**3♀**	**0**	**1♀**	**4**	**2.198**
Thiania bhamoensis (Thorell 1877)	**1♀**	**0**	**0**	**1**	**0.549**
Thyene cf. *manipisa* (Barrion et Litsinger 1995)	**1♀**	**0**	**0**	**1**	**0.549**
SPARASSIDAE (Giant Crab/Hunstman spiders)					
Heteropoda boiei (Doleschall 1859)^	**0**	**1♀**	**0**	**1**	**0.549**
Heteropoda cf. *boiei* (Doleschall 1859)	**0**	**0**	**1♀**	**1**	**0.549**
Heteropoda davidbowie (Jager 2008)^	**0**	**1♀**	**0**	**1**	**0.549**
Heteropoda cf. *davidbowie* (Jager 2008)	**1♀SA**	**0**	**0**	**1**	**0.549**
Heteropoda natans (Jager 2005)^	**0**	**1♀**	**0**	**1**	**0.549**
Heteropoda cf. *natans* (Jager 2005)	**0**	**0**	**1♀**	**1**	**0.549**
Heteropoda tetrica (Thorell 1897)^	**0**	**1♀**	**0**	**1**	**0.549**
Heteropoda venatoria (Linnaeus 1767)	**1i♀,1♀**	**1♀**	**0**	**3**	**1.648**
Heteropoda sp. 1	**1i♀**	**1♂,1♀**	**0**	**3**	**1.648**
Heteropoda sp. 2	**0**	**1♀**	**0**	**1**	**0.549**
Heteropoda sp. 3	**0**	**1♂SA**	**0**	**1**	**0.549**
Thelcticopis sp. 1	**1♀**	**0**	**0**	**1**	**0.549**
Thelcticopis sp. 2	**1♀**	**0**	**0**	**1**	**0.549**
Thelcticopis sp. 3	**1♀SA**	**0**	**1♀**	**2**	**1.099**
Thelcticopis sp. 4	**0**	**1♂SA,3♀**	**0**	**4**	**2.198**
Thelcticopis sp. 5	**0**	**0**	**1♀**	**1**	**0.549**
Thelcticopis sp. 6	**0**	**0**	**1♀**	**1**	**0.549**
TETRAGNATHIDAE (Long-jawed orb weaver)					
Leucauge argentina (Hasselt 1882*)*	**0**	**3♀**	**0**	**3**	**1.648**
Leucauge cf. *argentina* (Hasselt 1882)	**1♀**	**0**	**0**	**1**	**0.549**
Leucauge cf. *granulata* (Walckenaer 1841)	**0**	**3♀**	**0**	**3**	**1.648**
Leucauge sp.	**0**	**1♀**	**0**	**1**	**0.549**
Opadometa fastigata (Simon 1877)	**1♂SA,4♀**	**5♀**	**4♀**	**14**	**7.692**

SPIDERS FAMILY AND SPECIES	SITE 1	SITE 2	SITE 3	TOTAL	RA (%)
Opadometa sp.	**1♂**	**0**	**0**	**1**	**0.549**
Orsinome sp.	**0**	**0**	**1♀**	**1**	**0.549**
Orsinome vethi (Hasselt 1882)	**0**	**1♀**	**0**	**1**	**0.549**
Tetragnatha hasselti (Thorell 1890)	**0**	**0**	**1♀**	**1**	**0.549**
Tetragnatha sp. 1	**0**	**0**	**1♀**	**1**	**0.549**
Tylorida ventralis (Thorell 1877)	**0**	**1♀**	**0**	**1**	**0.549**
THERAPHOSIDAE (Tarantulas)					
Phlogiellus baeri (Haupt et Schmidt 2004)*	**0**	**0**	**1♀SA,2SA**	**3**	**1.648**
THERIDIIDAE (Comb footed/Sheet line Spiders)					
Argyrodes sp.	**0**	**0**	**1i**	**1**	**0.549**
Latrodectus sp.	**0**	**1♀**	**1♀**	**2**	**1.099**
Parasteatoda sp. 1	**0**	**1♀**	**1♀**	**2**	**1.099**
Parasteatoda sp. 2	**0**	**1♀**	**1♀SA**	**2**	**1.099**
Parasteatoda sp. 3	**0**	**1♀**	**0**	**1**	**0.549**
Parasteatoda sp. 4	**0**	**1♀**	**0**	**1**	**0.549**
Phoroncidia sp.	**0**	**1♀**	**0**	**1**	**0.549**
Steatoda sp.	**1♀**	**0**	**0**	**1**	**0.549**
Theridion sp. 1	**0**	**0**	**1♀SA,1♀**	**2**	**1.10**
Theridion sp. 2	**0**	**1i**	**0**	**1**	**0.549**
Theridula sp.	**0**	**1♀SA**	**0**	**1**	**0.549**
THOMISIDAE (Crab spiders)					
Borboropactus sp.	**0**	**1♀**	**0**	**1**	**0.549**
Misumena sp.	**0**	**0**	**1♀**	**1**	**0.549**
Thomisus callidus (Thorell 1890)^	**1♀**	**0**	**0**	**1**	**0.549**
Total no. of Individuals	**44**	**76**	**63**	**182**	
Total no. of Species	**35**	**52**	**47**	**108**	
Total no. of Genera	**26**	**33**	**37**	**96**	
Total no. of Families	**12**	**13**	**12**	**17**	
Total no. of Males	**9**	**7**	**5**	**21**	
Total no. of Females	**34**	**62**	**52**	**149**	
Total no. of Unclassified	**1**	**5**	**6**	**12**	

Table 1. Species richness and relative abundance of spiders in different sampling sites. Legend: Site 1 = Mixed Dipterocarp Forest. Site 2: Riparian forest. Site 3: Mixed Dipterocarp Forest with neighboring Agroecosystem. ♀- Female, ♂- Male, UC- unclassified, A-adult, SA- sub-adult, i- immature, RA (%)- Relative Abundance,^-New record * Philippine endemic.

most abundance (74 individuals), whereas site 3 had 63 individuals. Site 1 had the least number of species (35 species), while Site 2 had the highest species richness (49 species).

Tsai et al. (2006) reported that the spatial structure of the environment influences spider habitat preferences. This could explain the high spider species richness observed in both Sites 2 and 3 where vegetation seems more diverse due to the availability of freshwater stream in site 2 providing resources such as habitat and potential preys for spiders. In Site 3, the presence of neighboring agroecosystem provides the spiders an additional habitat. As the vegetation matures, becoming denser and stratified, more species and families of spiders are present (Lowrie, 1948). Spiders relocate webs in response to web destruction and rebuild them in sites where enough stable structure is provided (Hodge, 1988) and thus, it may explain why the neighboring site, Site 1, is more diverse.

Opadometa fastigata of Tetragnithidae emerged to be the most abundant spider species making up 7.692% of the total species collected including the fact that it is the most observed species during the sampling. It was evenly distributed in the sites.

Fifteen spiders were found to be new record species in the Philippines based on the World Spider Catalog (World Spider Catalog, 2018) and research studies. New records include *Anepsion depressum* (Thorell, 1877), *Clubiona biembolata* (Deeleman-Reinhold, 2001), *Clubiona corticalis* (Walckenaer, 1802), *Nusatidia camouflata* (Deeleman-Reinhold, 2001), *Burmattus pococki* (Thorell, 1895), *Myrmarachne malayana* (Edmunds & Proszynski, 2003), *Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869), *Phintella versicolor* (C.L. Koch, 1846), *Pristobaeus jocosus* (Simon, 1902), *Telamonia dimidiata* (Simon, 1899), *Heteropoda boiei* (Doleschall, 1859), *Heteropoda davidbowie* (Jager, 2008), *Heteropoda natans* (Jager, 2005), *Heteropoda tetrica* (Thorell, 1897), and *Thomisus callidus* (Thorell, 1890). So far, none of the species reported is classified as threatened in the International Union for Conservation of Nature red list of threatened species (IUCN, 2018). Two of the spiders are Philippine endemic based on the World Spider Catalog (World Spider Catalog, 2018). They are the *Calapnita subphyllicola* (Deeleman-Reinhold, 1986) and *Phlogiellus baeri* (Haupt & Schmidt, 2004).

Abundance and species richness of spider families

In terms of relative abundance, Table 2 shows that the major families are Salticidae (19.78%), Araneidae (18.13%), Tetragnathidae (15.39%), and Sparassidae (13.74%). Family Salticidae comprised most of the overall population. It dominated Sites 1 (25%) and 3 (26.98%). According to Lima-Peres et al. (2014), family Salticidae is the third most abundant family of spiders. Most of the spiders under this family were widely distributed in Site 3 with secondary growth and adjacent agroecosystem and thus providing a range of microhabitats. They occur in many microhabitats from under or below leaf litter up into the canopy (Richman et al., 2005). In Site 2, both families Araneidae (18.42%) and Tetragnathidae (18.42%) are the most abundant. Family Aranaeidae (18.13%), the orb weavers, ranked second in terms of overall population. The spiders of this family are evenly distributed both in Sites 3 and 2. According to Dacanay et al. (2014), Araneidae prefers locations that are highly influenced by the presence of vegetation and even near water systems, shaded vegetation,

	Relative Abundance (%)			
Family	SITE 1	SITE 2	SITE 3	Total
Araneidae	11.36	18.42	22.22	18.13
Clubionidae	6.82	6.58	0	4.396
Ctenidae	4.55	2.63	3.17	3.297
Deinopidae	2.27	0	0	0.549
Eutichuridae	0	1.32	0	0.549
Linyphiidae	0	1.32	0	0.549
Nephilidae	0	7.89	1.59	3.846
Oxyopidae	2.27	0	1.59	1.099
Pholcidae	6.82	0	3.17	2.747
Pisauridae	0	1.32	0	0.549
Psechridae	4.55	1.32	6.35	3.846
Salticidae	25	10.53	26.98	19.78
Sparassidae	15.91	17.11	7.94	13.736
Tetragnathidae	15.91	18.42	11.11	15.385
Theraphosidae	0	0	4.76	1.648
Theridiidae	2.27	10.53	9.52	8.242
Thomisidae	2.27	1.32	1.59	1.648

Table 2. Relative abundance of spider families per site and overall study area. Site 1 = Mixed Dipterocarp Forest. Site 2: Riparian forest. Site 3: Mixed Dipterocarp Forest with neighboring Agroecosystem.

traces of logs, trunks of trees, and fallen trees. Araneidae spiders are common on the foliage or canopy of the plant vegetation which serves as anchors to stabilize their webs (Barrion et al., 2012). All sites have with secondary vegetation and thus provide high opportunity for the family araneidae to build orb-webs and also provide high number of prey. Site 2 is a riparian forest with freshwater stream that provides nutrition for potential prey for spiders and thus attracts spiders to build their webs near the site.

Figure 4 shows that family Araneidae ranked first in terms of species richness (22 species) while Salticidae ranked second (21 species). Per site, Salticidae dominates both the forested sites, Site 1 (9 species) and Site 3 (13 species). The foliage runners have 21 species from 16 genera. In Site 2, the riparian forest, family Sparassidae has the most species (9 species). Spider families with low species richness include: Ctenidae (2 species), Deinopidae (1 species), Eutichuridae (1 species), Linyphiidae (1 species), Nephilidae (3 species), Oxyopidae (2 species), Pholcidae (3 species), Pisauridae (1 species), Psechridae (1 species), Theraphosidae (1 species), and Thomisidae (3 species). Low species richness of these families is attributed to the rainy condition during sampling which makes it harder for the spiders to be seen. Species richness may vary across seasons. This might have also affected the total spider family richness of the Mimbilisan Protected Landscape since sampling was carried out during the month of July, a rainy month. Thus, species richness in the area may be greater than the actual data generated.

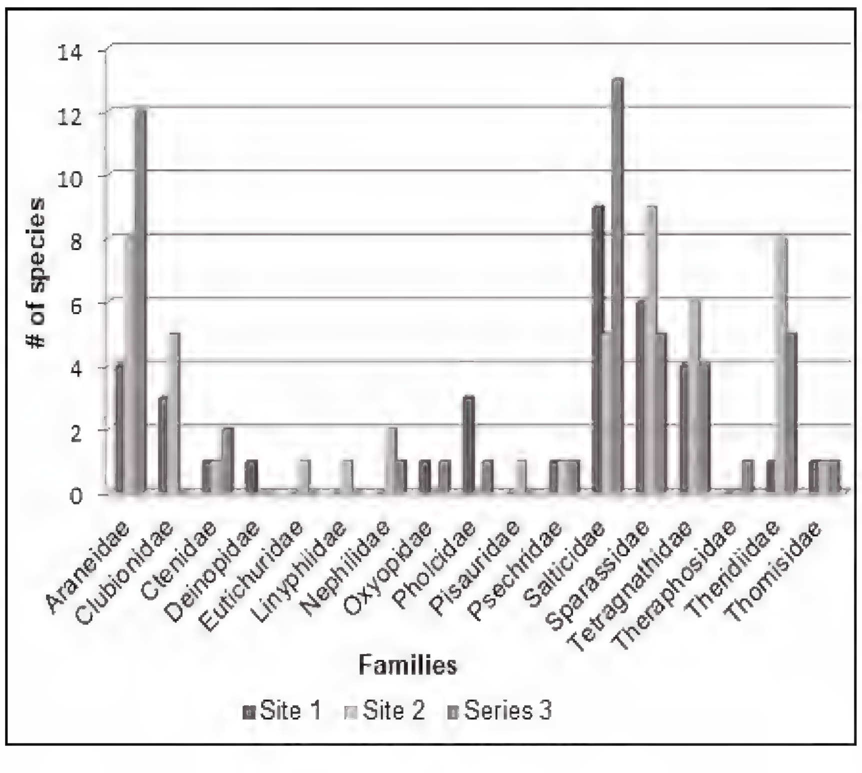

Figure 4. Number of species and family composition in each sampling site.

Eight families, namely Araneidae, Ctenidae, Psechridae, Salticidae, Sparassidae, Tetragnathidae, Theridiidae, and Thomisidae, were found to be present in all three sites indicating that they are well-adapted to these areas. Spider's ubiquity in different sites can be attributed to the good dispersal behavior of spiders. An act called ballooning allows spiders to travel from hundreds of meters to several kilometers (Bell et al., 2005). Four families, namely Clubionidae, Nephilidae, Oxyopidae, and Pholcidae, were observed in at most two sites. Spiders may have dispersed to another site due to the disturbances present which serve as their defense mechanism. One major key in surviving disturbances is through the ability of spiders to disperse (Moir et al., 2005). The families Deinopidae, Eutichuridae, Linyphiidae, Pisauridae, and Theraphosidae were only found at a single site but they are not considered as rare. Due to being cryptic or having a patchy distribution they may not have been adequately sampled (Patiño et al., 2016). It might also be due to the presence of a biotic and abiotic factors preferred by a species that cause it to be present only in a single site. According to Seyfulina (2005), both biotic and abiotic factors have different influences on the distribution of the different spider groups. It indicates that spatial variety of the vegetation may effect the spider diversity. For instance, *Phlogiellus baeri* can only be found in site 3 since in this site, light cannot easily penetrate due to high density of vegetation. The resulting low temperature and the presence of coconut husks are both preferred by *P. baeri* explaining its presence in this site.

Age and Sex Structure

Figure 5 shows the age and sex composition of recorded spiders. Collected spiders were a mixture of adults (82.32%), sub-adults (9.94%), and immatures (7.73%). Among the adult spiders, females were dominant (81.77%) and males are of low percentage (12.15%). The same findings were observed in a study on Mt. Matutum, South Cotabato (Garciano et al., 2014), Mt. Pinukis, Zamboanga del Sur (Lalisan et al., 2015), and in Marilog Dis-

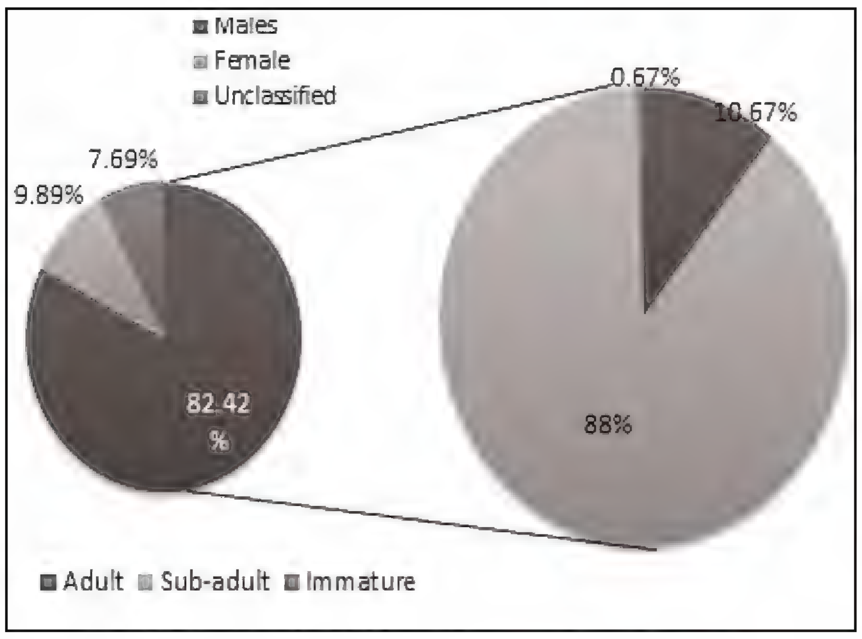

Figure 5. Age and sex percentage composition of collected individuals.

Indices	Site 1	Site 2	Site 3	Total
Species	35	52	47	108
Individuals	44	76	63	182
Shannon	3.432	3.781	3.739	4.418
Evenness	0.8838	0.8437	0.8946	0.7676

Table 3. Biodiversity indices of the three sampling sites.

trict, Davao City (Patiño et al., 2016). However, findings differed with the study in Rajah Sikatuna Protected Landscape, Bohol (Quiñones et al., 2016), where males dominated the area. Presence of dominant female spiders may be due to their morphological feature where male spiders are smaller (Wegner, 2011) and thus hard to be detected. Cannibalism behavior of female spider after mating is another factor where it is most widely observed in spiders (Elgar, 1992). Fatal encounter of males with potential predators during mate-searching is often ascribed to abundance of female spiders (Gaskett et al., 2004). Considering the fact that male spiders reach maturity faster than females, Romero & Vasconsellos-Neto (2005) observed that female spiders are more frequently observed during adult and sub-adult stages while male spiders are frequent during the juvenile stage. High number of collected adults were observed since female spiders oviposit throughout the entire year (Nieto-Castañeda et al., 2012). Female spiders typically have larger abdomens than males. The epigynum that can only be found in female spiders lies near the epigastric furrow and bears the openings to the seminal receptacles while the male reproductive system of spiders has a pair of coiled tubular testes in the opisthosoma, which lead to a common sperm duct that opens into the epigastric furrow (Foelix, 2011). According to Wegner (2011) males of some families have the first pair of legs longer and/or more stocky and hairy in proportion to their size. Males have species-unique pedipalps with enlarged tips serving as sex organ (Brown & Merchant, 2015).

Biodiversity Indices

Considering the importance of spiders in controlling insect pests and as bio-indicators, serious efforts are required in understanding their diversity (Umarani & Umamaheswari, 2013). Table 3 shows the biodiversity indices in the three sampling sites of Mimbilisan Protected Landscape, Misamis Oriental. High diversity and even species distribution were observed in all sites. Site 2 had the most abundant spiders with 76 individuals comprising 52 species. Site 3 had 63 individuals in 47 species. Site 1 had the least abundance of 44 individuals with 35 species. A riparian forest serves as a faunal corridor, connecting adjacent ecosystems (Raizer et al., 2005). Site 2 serves as the transition zone between Sites 1 and 3. Edge effect hypothesis states that species richness increases at the border between different habitats (Odum, 1971) and thus, Site 2 has the highest species richness. Presence of the stream in Site 2 provides nutrients to nearby vegetation allowing it to grow enormously which then provides adequate habitat for the spider fauna particularly for the orb weavers.

According to Murcia (1995), the edges lead to variations in plant physiological response, vegetation structure, and forest species composition. The stream also attracts potential prey for the spiders. Site 3 was second in terms of species richness due to the presence of cultivated crops introduced in the area. The physical structure and species composition of vegetation define diversity of species and abundance through habitat availability (Malumbres-Olarte et al., 2013). This indicates that Site 2 vegetation structure is favorable to spiders. Site 1 with the highly disturbed vegetation had the lowest species diversity compared to the other sites because it serves as the main port in accessing the stream near Site 2. Moreover, Site 1 was the most accessible and visited site with higher disturbance to potential prey and the spiders themselves therefore decreasing spider richness and abundance. Low species richness is attributed to disturbed sites (Maya-Morales et al., 2012). As disturbance increases, the spider species richness decreases (Pinkus et al., 2006). Dacanay et al. (2014) reported low spider abundance and richness in very disturbed areas. Following Pielou's evenness index, all three sampling sites were found to be evenly distributed, although Site 2 got the lowest value compared to the two sites, which means that a species dominates the area. In this case, it was dominated by the species *Opadometa fastigata*, the most abundant species in Mimbilisan Protected Landscape. In addition, although Site 2 had the highest species richness and species diversity, Site 3 still has the highest evenness. Changes in ecological gradients due to human activities influence spider distribution and alter the community's composition (Uetz, 1976). Even though the different sites vary in biodiversity indices, the overall diversity of Mimbilisan Protected landscape is relatively high (H'=4.36). Typically, values of Shannon-Wiener diversity index generally ranged from 1 to 3 which means that the diversity is moderate, low diversity if the index value is below 1, and high diversity if the index value is greater than 3 (Richardson, 1977). The value of H' increases as species richness and evenness increase.

Guild Structure

Guild structure of spiders is useful in studying ecology in describing diversity in communities (Freitas et al., 2013). The presence of this guild may be explained by the type of vegetation in the area which could provide adequate space of varying extent for building webs. Figure 4 shows the different guilds present in Mimbilisan Protected Landscape. The most dominant guild is the orb weavers comprising 37% of the distribution in the area. This guild is composed of families Araneidae and Tetragnathidae which were mostly collected in forest vegetation and bushes near the riparian forest, mostly in sites 3 and 2, respectively, which provided wider expanse for web building such as building web between branches/stems of plants. The same observation was obtained in the Philippines by Patiño et al. (2016) in Marilog District, Davao City and Juario et al. (2016) in Sacred Mountain in Marawi City and in China by Barrion et al. (2012) in their study in the rice agricultural landscape of Hainan Island,. Garciano et al. (2014) found the orb weavers to be the most abundant comprising 61% of their total collected specimens. They were mostly found in shrubs, best for anchoring their webs. Richardson & Hanks (2009) reported that the diversity of orb weavers is influenced by the floral community species composition. In this study (Fig. 6), web-building spiders are expected to be abundant because of the existence of bushes in the forested areas. Furthermore, since the forest is a secondary vegetation it provides more opportunity for the orb-weavers to build their webs around. The differences in web support structures brought about by the differences in microhabitats also affect spider density (Balfour & Lypstra, 1998). Foliage runners formed the next dominant guild (26%) in Sites 1 and 2 and the dominant guild in Site 3 which were commonly found above or beneath leaves. The spatial complexity of the leaf litter facilitates the existence of several species because it provides high surface

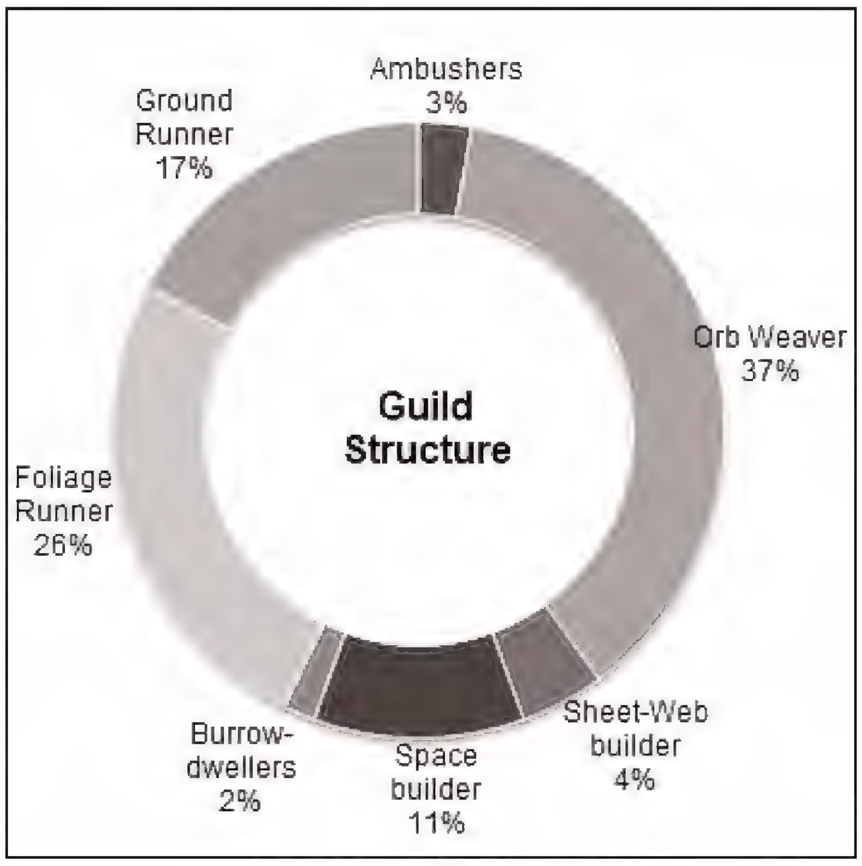

Figure 6. Percentage distribution of the different spider guilds at Mimbilisan Protected Landscape.

area and foraging spaces within the leaves (Uetz, 1991). Most of the vegetation in the forest consisted of high surface leaves and thus provide more opportunity for the foliage runners. The most abundant ground vegetation was *Schismatoglottis calyptrata* locally called "dalili" which has high surface area. Ground runners (Ctenidae and Sparassidae) have 17% of the total relative abundance. Forest areas have leaf litter and provide opportunity for the ground runners. Space builders (Theridiidae and Pholcidae) have 11% relative abundance while sheet web weavers (Linyphiidae and Psechridae) have 4%. Branches/stem of plants and rocks provide these space builders and sheet web weavers spaces/areas to anchor their webs. Ambushers (Deinopidae, Thomisidae and Pisauridae) have 3% and burrow-dwellers (Theraphosidae) have 2% of the guild distribution. Mosses, humus, cover plants, and rocks on forest floor provide habitats for ambushers and burrow dwellers. In addition, according to Freitas et al. (2013), the dry climate and exposure to sunlight favor nocturnal ground hunters and runners.

Spider Microhabitats

Mimbilisan Protected landscape provides a variety of possible microhabitats for the spider fauna. Microhabitats include the branches/stem of plants, leaf surfaces/foliage, *Schismatoglottis calyptrata* locally called "dalili", forest floor, rocks, leaf litter, coconut husk, and fallen logs. The branches/stem of plants were used by spiders to anchor their webs and most of the jumping spiders were found hiding on or under leaf surfaces/foliage. *Schismatoglottis calyptrata* was the most observed ground vegetation providing a high surface area for the foliage runners. Mosses, humus, rocks, and cover plants on the forest floor provide opportunity for ambushers and burrowing spiders to hide on. Rocks serve as microhabitat for the ground dwelling spiders and some orb weavers. Leaf litter provides the ground dwelling spiders a microhabitat. Coconut husks serve as microhabitat for *Phlogiellus baeri* and it is here where *Phlogiellus baeri* can only be found. Some of the spiders such as the burrowing spiders were found on fallen logs. It seems that Site 1 with high disturbance and low diversity provides high number of microhabitats for the spiders. Foliage, stems, and fallen logs were found in all sites. Leaf litter and forest floor serve as the general microhabitat for ground-dwelling and burrowing spiders. *Schismatoglottis calyptrata* that was only found in forested area greatly provides microhabitat for spiders especially for leaf-dwelling spiders. In riparian forest, rocks are the microhabitat for both ground-dwelling and orb-weaver spiders. Lastly, in agro-ecosystem part of Site 3, coconut husk provides microhabitat for numerous *Phlogiellus baeri*.

Table 4 shows the different species of spiders documented with their respective microhabitats. Studies of relationships between spiders and the structure of habitats have shown that spiders use structures in their environment as cues to habitat quality, architectural foundations for prey-catching webs, and as vibration-conducting and monitoring surfaces in communication and prey capture (Uetz, 1991). The most utilized microhabitats by the spiders are between branches/stem of plants and leaf surfaces/foliage. This explains why the orb-weavers and foliage runners were the most abundant guilds in the area to which the families Araneidae and Salticidae, the most abundant families with high species richness, belong, respectively. Possible factors that affect microhabitat selection include prey availability, leaf toxicity, and suitability of leaf structure for web attachment. According to Huber & Schutte (2009), underlying mechanism is difficult to resolve due to the presence of factors influencing the spider's microhabitat choice.

CONCLUSIONS

Mimbilisan Protected Landscape has a relatively high species richness and high overall diversity of spiders. One-hundred eight species of spiders across the sampling sites were evenly distributed. Fifteen spider species are new record to the Philippines. Two spider species are Philippine endemic. About 82.32% of spiders are adult and mostly female (81.77%). There were 17 families recorded in which Salticidae was the most abundant family. In terms of species richness, family Araneidae ranked first (22 species) and Salticidae was close behind (21 species). Of the seven guilds recorded, orb weavers were the most distributed,

Spider species	Microhabitat
Araneidae	
Anepsion depressum	*Schismatoglottis calyptrata (*locally called *"dalili")* leaf surface
Anepsion roeweri	*Schismatoglottis calyptrata*leaf surface
Anepsion sp.	On the web between branches/stem of plants
Araneus sp.	On the web between branches/stem of plants
Argiope aemula	On the web between branches/stem of plants
Cyclosa sp. 1	On the web between branches/stem of plants
Cyclosa sp. 2	*Schismatoglottis calyptrata locally* leaf surface, Leaf surfaces/foliage
Cyrtophora sp.	Leaf surfaces/foliage, On the web between branches/stem of plants
Eriovixia laglaizei	Leaf surfaces/foliage
Eriovixia cf. *laglaizei*	Leaf surfaces/foliage
Eriovixia sp. 1	On the web between branches/stem of plants
Eriovixia sp. 2	Leaf surfaces/foliage
Gasteracantha doriae	On the web between branches/stem of plants
Hyposinga sp.	Forest floor
Neoscona cf. *nautica*	On the web between branches/stem of plants
Neoscona nautica	Leaf surfaces/foliage
Neoscona punctigera	On the web between branches/stem of plants
Neoscona sp.	On the web between branches/stem of plants
Poltys sp.	On the web between branches/stem of plants
Singa sp.	On the web between branches/stem of plants
Thelacantha brevispina	Leaf surfaces/foliage
Verrucosa sp.	Leaf surfaces/foliage, On the web between branches/stem of plants
Clubionidae	
Clubiona biembolata	On the web between branches/stem of plants
Clubiona corticalis	Forest floor
Clubiona cf. *japonicola*	Leaf surfaces/foliage
Clubiona sp.	Leaf surfaces/foliage
Clubionidae immature	On the web between branches/stem of plants
Nusatidia camouflata	*Schismatoglottis calyptrata*, On the web between branches/stem of plants
Pristidia longistila	On the web between branches/stem of plants
Ctenidae	
Ctenus sarawakensis)	Forest floor, Leaf litter, Fallen logs
Ctenus sp.	Forest floor
Deinopidae	
Deinopis sp.	On the web between branches/stem of plants
Eutichuridae	
Cheiracanthium sp.	On the web between branches/stem of plants
Linyphiidae	
Plectembolus sp.	On the web between branches/stem of plants
Nephilidae	
Nephiladae immature	On the web between branches/stem of plants
Nephila pilipes	Leaf surfaces/foliage, On the web between Branches/stem of plants
Herrenia sp.	On the web between branches/stem of plants
Oxyopidae	
Hamadruas cf. *hieroplyphica*	On the web between branches/stem of plants
Oxyopes lineatipes	Leaf surfaces/foliage
Pholcidae	
Calapnita deelemanae	*Schismatoglottis calyptrata*, Leaf surfaces/foliage
Calapnita subphyllicola	*Schismatoglottis calyptrata*, Leaf surfaces/foliage, On the web between branches/stem of plants
Pholcus sp. 1	Forest floor
Pisauridae	
Hygropoda sp.	Leaf surfaces/foliage
Psechridae	
Psechrus sp.	On the web between branches/stem of plants, Forest floor
Salticidae	
Bavia aericeps	*Schismatoglottis calyptrata*, Leaf surfaces/foliage
Bavia sexpunctata	Leaf surfaces/foliage, On the web between Branches/stem of plants
Burmattus pococki	Leaf surfaces/foliage
Cosmophasis sp. 1	Leaf surfaces/foliage, On the web between branches/stem of plants
Cosmophasis sp. 2	Leaf surfaces/foliage
Evarcha sp.	Leaf surfaces/foliage
Epeus sp.	On the web between branches/stem of plants
Hasarius adansoni	Leaf surfaces/foliage
Myrmarachne malayana	On the web between branches/stem of plants, Forest floor
Myrmaplata plataleoides	On the web between branches/stem of plants, Leaf litter
Phintella versicolor	Leaf surfaces/foliage, On the web between branches/stem of plants
Plexippus paykulli	Leaf surfaces/foliage, On the web between branches/stem of plants
Portia sp.	Leaf surfaces/foliage
Pristobaeus jocosus	On the web between rocks
Pseudeuophrys sp.	On the web between branches/stem of plants
Salticidae immature	On the web between branches/stem of plants
Telamonia dimidiata	Leaf surfaces/foliage
Telamonia cf. *festiva*	Leaf surfaces/foliage, On the web between branches/stem of plants
Thiania bhamoensis	Leaf litter
Thyene cf. *manipisa*	Leaf surfaces/foliage
Sparassidae	
Heteropoda boiei	Forest floor
Heteropoda cf. *boiei*	Leaf litter
Heteropoda davidbowie	On the web between branches/stem of plants
Heteropoda cf. *davidbowie*	Forest floor
Heteropoda cf. *natans*	Leaf surfaces/foliage
Heteropoda natans	Leaf surfaces/foliage
Heteropoda venatoria	On the web between branches/stem of plants, Forest floor
Heteropoda sp. 1	Forest floor, On the web between rocks
Heteropoda sp. 2	On the web between rocks
Heteropoda sp. 3	On the web between rocks
Thelcticopis sp. 1	Leaf litter
Thelcticopis sp. 2	Forest floor
Thelcticopis sp. 3	Forest floor, Leaf litter
Thelcticopis sp. 4	Forest floor, Leaf litter
Thelcticopis sp. 5	On the web between branches/stem of plants
Thelcticopis sp. 6	Forest floor
Tetragnathidae	
Leucauge argentina	Leaf surfaces/foliage, On the web between branches/stem of plants, On the web between rocks
Leucauge cf. *argentina*	On the web between branches/stem of plants
Leucauge cf. *granulata*	Leaf surfaces/foliage, On the web between branches/stem of plants
Leucauge sp.	Leaf surfaces/foliage
Opadometa fastigata	Leaf surfaces/foliage, On the web between branches/stem of plants, On the web between rocks
Opadometa sp.	Leaf surfaces/foliage
Orsinome sp.	Leaf surfaces/foliage, On the web between branches/stem of plants
Orsinome vethi	Leaf surfaces/foliage
Tetragnatha hasselti	*Schismatoglottis calyptrata*, Leaf surfaces/foliage
Tetragnatha sp. 1	*Schismatoglottis calyptrata*, Leaf surfaces/foliage
Tylorida ventralis	Leaf surfaces/foliage
Theraphosidae	
Phlogiellus baeri	Coconut husk
Theridiidae	
Argyrodes sp.	Leaf surfaces/foliage
Latrodectus sp.	Leaf surfaces/foliage
Parasteatoda sp. 1	Leaf surfaces/foliage, On the web between branches/stem of plants
Parasteatoda sp. 2	Leaf surfaces/foliage, On the web between branches/stem of plants
Parasteatoda sp. 3	Leaf surfaces/foliage
Parasteatoda sp. 4	Leaf surfaces/foliage
Phoroncidia sp.	*Schismatoglottis calyptrata* leaf surface, Leaf surfaces/foliage
Steatoda sp.	On the web between branches/stem of plants
Theridion sp. 1	Leaf surfaces/foliage, On the web between branches/stem of plants
Theridion	On the web between branches/stem of plants
Theridula	Leaf surfaces/foliage
Thomisidae	
Borboropactus sp.	On the web between branches/stem of plants
Misumena sp.	On the web between branches/stem of plants
Thomisus callidus	On the web between branches/stem of plants

Table 4. Microhabitats used by the spiders in Mimbilisan Protected Landscape.

being found in all sites. *Opadometa fastigata*, an orb-weaver, appears to be the most widely distributed species. Microhabitats were mostly branches/stems of plants and leaf surface/foliage. Results indicate that Mimbilisan Protected landscape is a highly diversified area which indicates a healthy ecosystem. Habitat structure, availability of microhabitat, and habitat disturbances appear to influence the diversity, distribution, and abundance of the spider species.

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New data on the presence of the Aesculapian snake *Zamenis longissimus* (Laurenti, 1768) (Serpentes Colubridae) on Elba Island (Tuscany, Italy)

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ABSTRACT We report three new findings of *Zamenis longissimus* on Elba Island (Tuscany, Italy), including two alive adult individuals and one dead young specimen. These records are a confirmation of the presence of an Aesculapian snake population on the island.

KEY WORDS Aesculapian snake; Elba; Italy; Serpentes; *Zamenis longissimus.*

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INTRODUCTION

Elba Island, with an area of about 223.5 km^2, is the third largest Italian island.

It is located in the central-northern Tyrrhenian Sea and it is part of the Tuscan Archipelago (which includes 7 main islands and about 20 smaller islands), belonging to the Province of Livorno, Tuscany. Its territory is mainly mountainous and the geology is quite complex (in short, there are metamorphic, magmatic and sedimentary elements). The hydrographic network is poorly developed (mainly with torrential waterways) due to the morphology of the area and the relatively small size of the island. The island has a Mediterranean oceanic pluvistational bioclimate. The current Elba's vegetation is strongly affected by anthropic interventions and afforestations mainly consist of *Pinus pinea* Linnaeus, 1753, followed by *P. pinaster* Aiton, 1789, *Quercus ilex* Linnaeus, 1753, *Castanea sativa* Miller, 1768 and other pine species. However, several reforestations are affected by a good renaturalization rate (Foggi et al., 2006).

From a biogeographical point of view, the fauna of Elba Island has a remarkable affinity with the one of the Tyrrhenian sector of Italy, in particular with Tuscany (cfr. Mertens, 1955). Herpetological colonization is partly linked both to Elba's geological history (for a summary, see Fornasiero & Zuffi, 2006; Vanni & Nistri, 2006; Vaccaro & Turrisi, 2007; Fattorini, 2010) and to anthropic causes, as in the case of terrestrial tortoises and their controversial autochthony (Fornasiero & Zuffi, 2006). Despite the lack of fossil remains (Fornasiero & Zuffi, 2006), recent biogeographical analyses based on the current Elba's fauna have made it possible to formulate some hypotheses on the dynamics of the animal colonization of the Tuscan Archipelago (Fattorini 2009, 2010), during a complex geological period such as the Pleistocene. According to the most accredited theses, during the Wurmian (22.000-18.000 years ago), Elba Island, together with Pianosa and Scoglio d'Africa, were connected to the Tuscan coast by a natural bridge that probably favoured the active passage of many vertebrates from the continent (Masetti & Rustioni, 1996; Fornasiero & Zuffi, 2006; Vaccaro & Turrisi, 2007; Fattorini, 2010).

As for the island's snake fauna, in addition to the Aesculapian snake covered by this study, there are four other taxa: *Coronella austriaca* Laurenti, 1768, *Hierophis viridiflavus* (Lacépède, 1789), *Natrix helvetica* (Lacépède, 1789) and *Vipera aspis francisciredi* (Laurenti, 1768) (Sindaco et al., 2006).

The Aesculapian snake *Zamenis longissimus* (Laurenti, 1768) is a monotypic species with a Siberian-European (European) and Mediterranean chorotype (Sindaco et al., 2013). Its range includes a large part of south-central and eastern Europe, ranging from north-eastern Spain to Asia Minor. In Italy, *Z. longissimus* occupies northern and central regions, reaching Lazio and Molise in the south (Di Nicola et al., 2019). Its presence in Sardinia is doubtful and based on isolated records, some of which attributable to *Z. lineatus* (Camerano, 1891): evidence of populations for both species have never been found there (Sindaco et al., 2006; Sindaco et al., 2013; Di Nicola et al., 2019). In Apulia, there are populations that show intermediate phenotype with *Z. lineatu*s (Salvi et al., 2017). This last taxon, previously considered a subspecies of *Z. longissimus* and then raised to a specific rank (Lenk & Wüster, 1999), is endemic to Italy and it is present in southern regions and Sicily (reaching Molise and southern Lazio in the north, where also *Zamenis longissimus* is present) (Corsetti & Romano, 2008; Capula et al., 2018; Di Nicola et al., 2019).

MATERIAL AND METHODS

The presence of the Aesculapian snake on Elba Island was mentioned for the first time by Sochurek (1954) but was not considered reliable by Mertens (1955) and Lanza (1996) as it was not supported by any findings. The species was then mentioned for the island in the books of Bruno (1984, 1998) and Bruno & Maugeri (1990), but also in this case without any finding or precise reference to support it.

Therefore, without confirmation of presence, the Aesculapian snake was not considered part of Elba's herpetofauna in the national (Sindaco et al., 2006) and regional (Vanni & Nistri, 2006) atlases. Thereafter, the presence of *Z. longissimus* on Elba Island was confirmed by the discovery of two dead specimens (an adult female and a juvenile, respectively in June 2002 and June 2005) in the same location in the north-eastern part of the island (Vaccaro & Turrisi, 2007). After these findings, there were no records for the species for several years and sightings of living individuals were missing in any case.

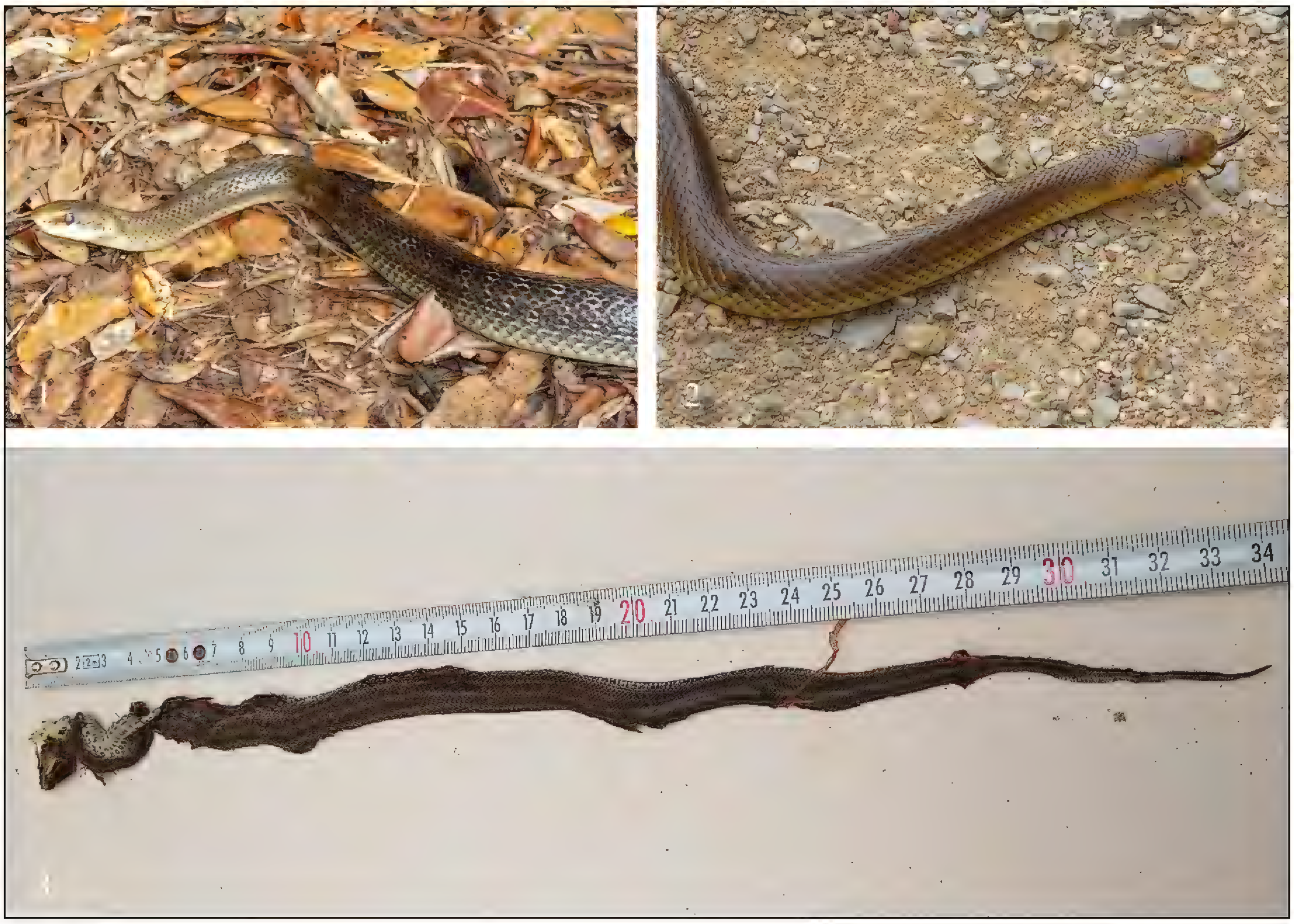
In this note, we report the finding of three further Aesculapian snakes, including living individuals. The first of the new findings was an alive adult female (Fig. 1), 142 cm long, observed near Mount Lentisco, along the path "Cala Mandriola - Cavo" (Municipality of Rio Marina) on June 4th, 2012 at about 6.10 pm (coordinates: 42°51'46.9"N, 10° 24' 29.7"E; altitude 105 meters a.s.l.). The second finding was an alive adult male (Fig. 2), 135 cm long, observed near Monte Lentisco, along the path above "Cala Forno la Vecchia" (Municipality of Rio Marina) on June 7th, 2012 at about 5.45 pm (coordinates: 42°51'58.4"N, 10°24'26.9"E; altitude 94 meters a.s.l.). The third finding was a young specimen (Fig. 3), about 34 cm long, found dead (roadkilled) along an asphalted road in the locality Vigneria (Municipality of Rio Marina) on September 23rd, 2019 at 1.00 pm (coordinates: 42°49' 27.7"N, 10°25'38.5"E; altitude 39 meters a.s.l.).

All three findings were at the edge of a road that crosses a dense holm oak forest, similarly to the location of the first two finds reported in Vaccaro & Turrisi (2007). Considering the findings reported in Vaccaro & Turrisi (2007), a total of five Aesculapian snakes have been found since 2002 (Fig. 4).

RESULTS AND DISCUSSION

Italian islands are connected daily by numerous naval connections with the mainland, in order to allow a continuous transit of goods and passengers. This can be the cause of involuntary translocations of wild animals including snakes, as it happened for example several times in Sardinia, where individual findings of allochthonous herpetological species have been made, whose origin was attributable to specific peninsular locations (Di Nicola & Mezzadri, 2018). Therefore, on an island, a single observation of an unknown entity should be treated cautiously before talking about the presence of a new species for that territory, at least until further observations.

Otherwise, the finding of adults of both sexes and young individuals of *Z. longissimus* reported in



Figures 1–3. The last three *Zamenis longissimus* findings from Elba Island: alive adult female from June 4th, 2012 (Fig. 1); alive adult male from June 7th, 2012 (Fig. 2); dead young specimen from September 23rd, 2019 (Fig. 3).

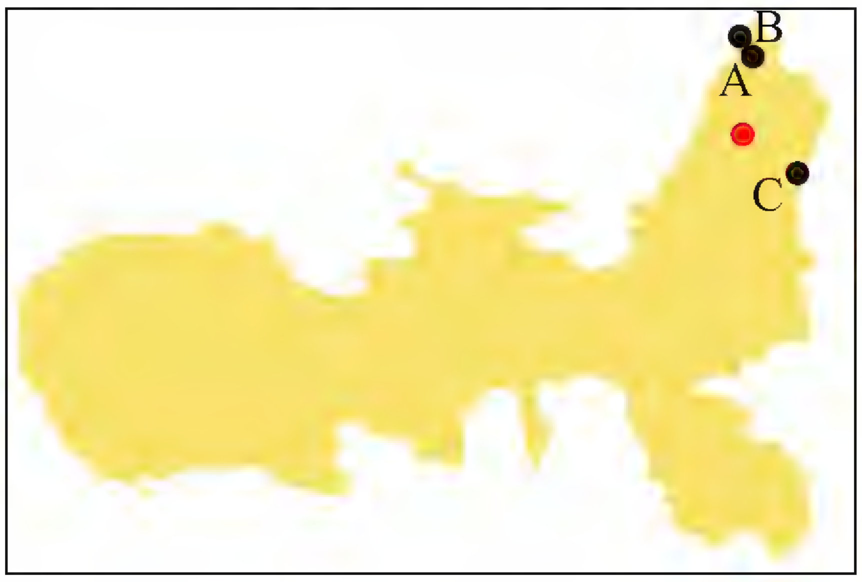


Figure 4. Map of Elba island with all *Zamenis longissums* findings: the red dot represents the old two findings reported by Vaccaro & Turrisi (2007); the black dots represent the three findings (A, B, C) reported in this note.

this note, added to the two findings reported in Vaccaro & Turrisi (2007), suggests the presence of a stable population of the species on Elba, at least in the north-eastern sector of the island, which is the most investigated by the authors (lack of reports elsewhere on the island could be attributed to a lack of previous researches).

The authors take advantage of this note to correct the discovery dates of the two specimens of *Z. longissimus* mentioned in Vaccaro & Turrisi (2007) indicated, following a typo, as August 8th, 2002 (adult female specimen) and August 6th, 2005 (young specimen): the correct discovery dates are June 8th, 2002 and June 10th, 2005 respectively. The location of these two first records (occurred in the same point after 3 years) is now also indicated: Case Nardelli (Municipality of Rio Marina) (coordinates: 42°50’18.1”N, 10°24’25.9”E; altitude 173 meters a.s.l.).

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Melanism in *Vipera aspis francisciredi* (Laurenti, 1768) (Reptilia Serpentes) in the Lazio Region (Parco Naturale Regionale dei Monti Simbruini), Italy

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ABSTRACT With this note we report the presence of melanic individuals of Redi's viper *Vipera aspis francisciredi* (Laurenti, 1768) (Reptilia Serpentes) in the Lazio region (Parco Naturale Regionale dei Monti Simbruini), Italy. Although the presence of melanic and melanistic individuals in the region is known, up to date, there are no official reports of this, in particular with regard to the territory of the Parco Naturale Regionale dei Monti Simbruini. The distribution on the national territory of melanic and melanistic individuals belonging to the subspecies *Vipera aspis francisciredi* is little known, therefore more in-depth studies on the distribution of the melanic phenotype in Italian populations would be of particular interest.

KEY WORDS Melanism;Parco Naturale Regionale dei Monti Simbruini; Redi's viper; *Vipera aspis francisciredi.*

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INTRODUCTION

Melanism is an excess of black pigmentation due to overproduction and/or dispersion of melanin from melanophores (tegumentary cells containing melanins belonging to the chromatophores category) (Sherbrooke et al., 1989) that can be found in many animal species, including snakes. In ectotherms, at similar values of temperature, solar radiation intensity and wind speed, individuals with a dark phenotype (with low reflectivity on the skin) warm up more quickly and consequently are able to maintain optimal body temperatures more easily than lighter coloured individuals (De Jong et al., 1996; Clusella-Trullas et al., 2007). At the same time, darker individuals are less cryptic, and therefore more vulnerable to predation (Clusella-Trullas et al., 2007). Melanic specimens are able to colonize environments with a greater plant cover, and therefore cooler and wetter, thanks to the superior heat absorption capacity due to the dark color; accordingly, the disadvantage due to reduced cryptic capacities is probably compensated by the speed with which the ideal temperature can be reached (Castella et al., 2013).

Vipera aspis francisciredi (Laurenti, 1768) (Reptilia Serpentes) is a subspecies of *V. aspis* (Linnaeus, 1758) present in central and northern Italy, southern Switzerland and Slovenia, with dorsal patterns consisting of small bands, dark-coloured spots or triangles and the accentuated polymorphism of the basic colour covering a wide range of grey, reddish, brown and sand tones. Regarding melanic specimes of this species, there is one area in central Italy where partially or totally black individuals live, but whose presence has never been officially registered in the Italian Lazio Region.

See also other cited references: Bruno, 1976, 1985; Brodmann, 1987; De Smedt, 2006; Di Nicola et asl., 2019.

MATERIAL AND METHODS

The specimens reported in Table 1 were sighted during the monitoring of the project "I rettili del Parco Naturale Regionale dei Monti Simbruini" and where, when possible, captured, sexed and released at the place of capture (Figs. 1–4).

A report was also collected together with photographic material from the Park staff and two specimens preserved under alcohol from a private collection and conserved in the "Museo della civiltà contadina" in Filettino (Frosinone, Italy) (Table 1).

Field work was carried out in the Regional Natural Park of the Simbruini Mountains (PNRMS), established in 1983, that with its about 30,000 hectares is the largest protected area in the Lazio Region, characterized by a low level of anthropization and a wide spread of forests: about 70% of the surface is in fact covered by forest formations of both beech forests and mixed deciduous and coniferous reforestation.

The Park territory is included in 7 municipalities: Camerata Nuova, Cervara di Roma, Subiaco, Jenne and Vallepietra in the province of Rome, Trevi nel Lazio and Filettino in the province of Frosinone. The protected area is included almost entirely in the SPA Monti Simbruini - Monti Ernici IT6050008 and includes 7 Sites of Community Importance (SIC).

DISCUSSIONS AND CONCLUSIONS

Melanism is frequent in a polymorphic taxa such as the genus *Vipera* Laurenti, 1768. In particular in Italy, the presence of melanic individuals of *Vipera berus* (Linnaeus, 1758) and *Vipera walser* Ghielmi, Menegon, Marsden, Laddaga et Ursenbacher, 2016 along the Alpine arc is known, On the contrary, the presence of melanic or melanistic individuals of *Vipera ursinii* has never been recorded in the peninsula. Among the Italian species, the one that presents the greatest variability in terms of coloration and dorsal ornamentation is certainly *Vipera aspis* (Linnaeus, 1758), mainly due to its wide distribution along the peninsula and the rich variety of colonized habitats. Melanism is relatively common among the individuals of *Vipera aspis aspis*, distributed in alpine habitats, but regarding *Vipera aspis* hugy, with such coloration, there is only one report (Di Nicola & Meier, 2013), while for *Vipera aspis francisciredi* its presence, over the years, has been sporadically reported in the literature, along the distribution range of this subspecies.

Given the altitudinal distribution of the individuals found during the present study (average elevation 1587.75 m) and their presence within the vegetation limits, it is possible to assume that melanism in *Vipera aspis francisciredi* is mainly due to thermoregulatory requirements due to the advantage given by a dark coloration in cool areas with wide tree cover (consequently shady and with low presence of predators such as birds of prey)

Sex	Date	SVL	Altitude	Habitat
F	22.V.1985	50 cm	1400 m	-
M	30.IX.1985	56 cm	1604 m	-
-	07.VII.2015	-	1740 m	bushy pasture
-	01.IX.2016	-	1596 m	forest
M	15.VII.2018	-	1727 m	forest
F	06.IX.2018	-	1718 m	bushy pasture
-	12.VII.2018	-	1483 m	forest
F	10.IX.2019	60 cm	1434 m	forest

Table 1. Baselines features of the studied specimens of melanic *Vipera aspis francisciredi*.

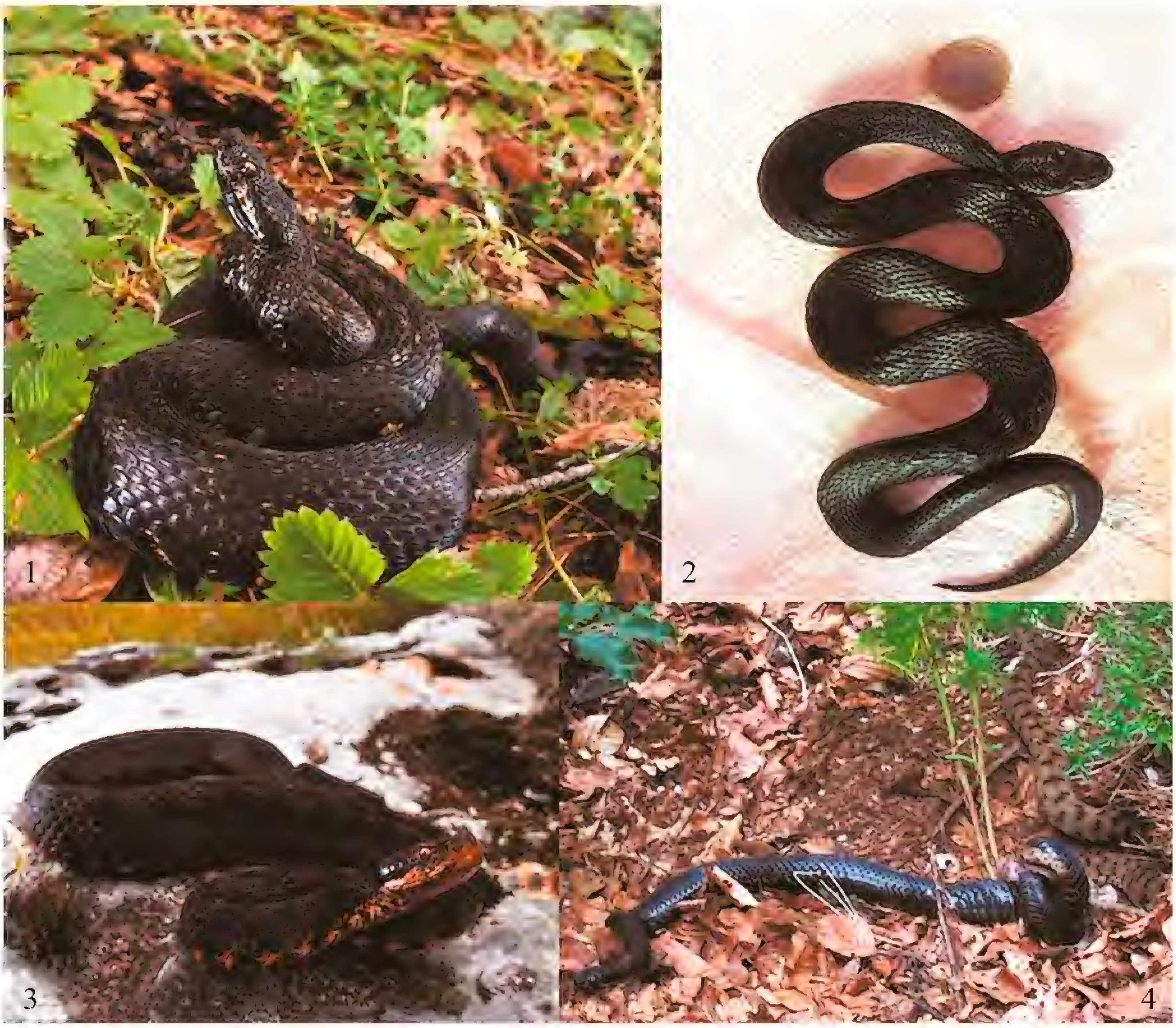

Figure 1. Male specimen observed on the edge of a beech forest (Filettino, Frosinone, Italy). Figure 2. Male specimen preserved under alcohol and belonging to a private collection (Filettino, Frosinone, Italy). Figure 3. Female specimen observed in a bushy pasture (Filettino, Italy). Figure 4. Mating between a melanic individual and one with normal phenotype (Guarcino, Frosinone, Italy).

(Castella et al., 2013). It would therefore be appropriate to deepen the research by including a larger number of individuals and populations, focusing attention on their distribution and fitness of melanic individuals compared to those with cryptic coloration present in the same area.

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First record of Turkish Gecko *Hemidactylus turcicus* (Linnaeus, 1758) populations for Piedmont, Italy (Sauria Gekkonidae)

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ABSTRACT This work reports the first occurrence of *Hemidactylus turcicus* (Linnaeus, 1758) (Sauria Gekkonidae) populations in Piedmont (Italy), one in the city of Turin and the other in Valle Talloria, Cuneo Province. They represent two new northern mainland sites for the species, which likely arrived in these areas by indirect anthropic transport.

KEY WORDS *Hemidactylus turcicus*; new record; Piedmont; population; Turkish Gecko.

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INTRODUCTION

The Turkish Gecko *Hemidactylus turcicus* (Linnaeus, 1758) is a polytypic species with a circum-mediterranean distribution and a complex systematic framework (Sacchi & Delaugerre, 2011). In Italy, it is mainly distributed in coastal areas and on most of the islands, with more records for the Tyrrhenian side than for the Adriatic one (Venchi, 2006; Sacchi & Delaugerre, 2011; Di Nicola et al., 2019). The species prefers rocky habitats, both natural and anthropic, and it is more active at dusk and at night (Speybroeck et al., 2016; Di Nicola et al., 2019). *Hemidactylus turcicus* is not considered as a threatened species and is listed as Least Concern (LC) both in the national and global IUCN Red Lists (Rondinini et al., 2013; IUCN, 2019).

Although the origins of the Italian *H. turcicus* populations are not sufficiently investigated, the populations of the inland areas of northern regions and north of the Conero on the Adriatic coast are likely to be present due to anthropic introduction and subsequent acclimatization (Venchi, 2006; Sacchi & Delaugerre, 2011). Similarly to what has been hypothesised for the Moorish Gecko *Tarentola mauritanica* (Linnaeus, 1758), the introduction of the Turkish Gecko in the inland areas of Northern Italy could have occurred by accidental transport by trucks, trains or ships, by vehicles of tourists returning home from Mediterranean locations and, to a lesser extent, by voluntary releases (Nardelli et al., 2016; Novarini, 2017). Both species are synanthropic and well adapted to living in urban contexts (Bonardi & Sindaco, 2004; Di Nicola et al., 2019).

Herein we report the first records of *H. turcicus* populations for the Piedmont region, which are added to the naturalised populations of this species that have already been observed in several areas of Northern Italy, in particular in the Po Valley (e.g. Bonardi & Sindaco, 2004; Benà, 2007; Nardelli et al., 2016; Novarini, 2017; Pegorini & Ghezzi, 2019).

MATERIAL AND METHODS

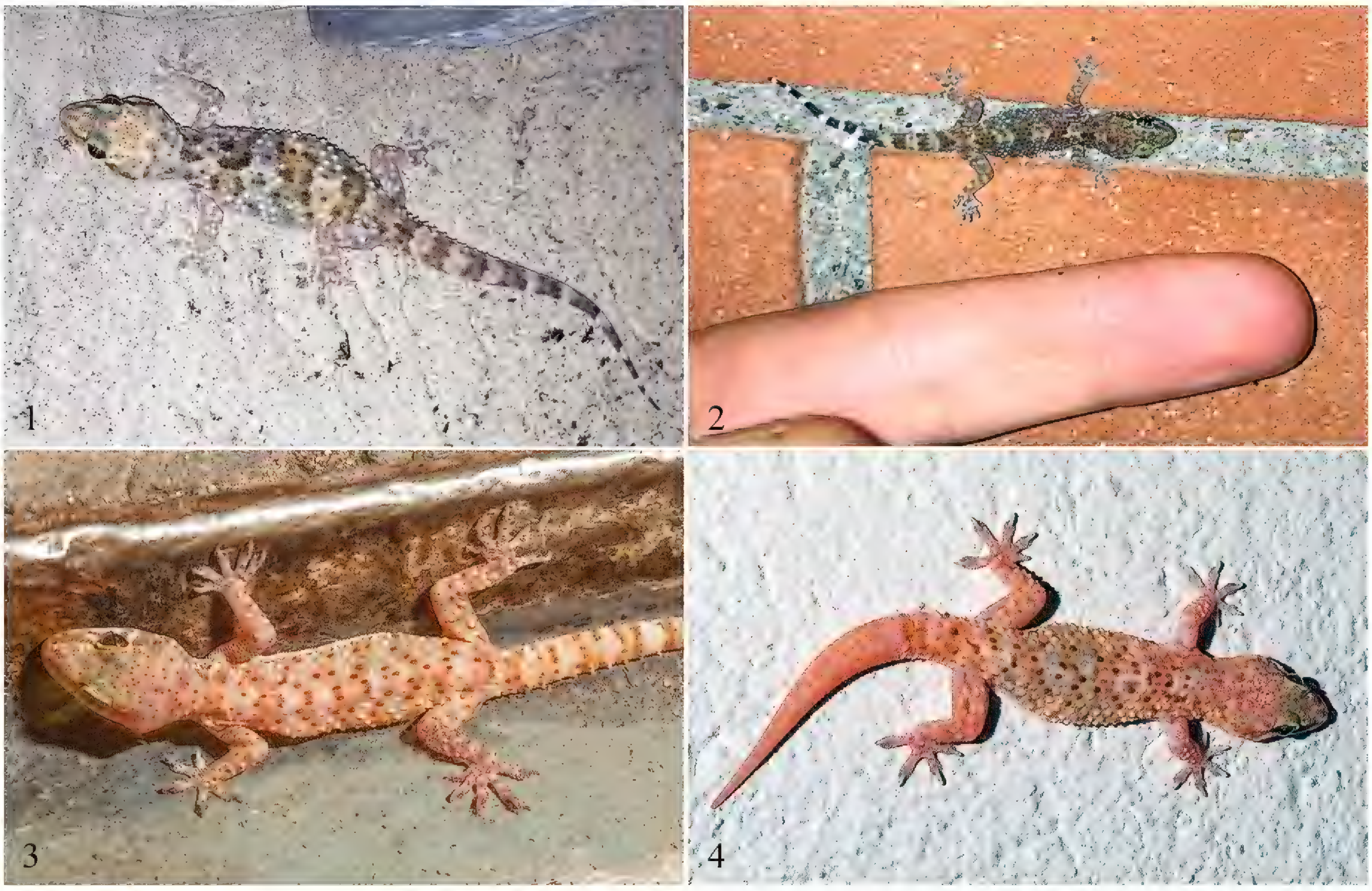
In Summer 2019, one of the authors (D.R.) found several individuals of Turkish Gecko, both adults and juveniles, on the wall of an apartment building situated on Via Pietro Cossa, Turin (258 m a.s.l., coordinates: 45°05’45”N, 7° 38’17”E) (Figs. 1, 2). More specifically, the geckos were spotted on three different days: a single adult individual observed on 17th July 2019; four new adult individuals and one juvenile observed on 2nd August 2019; another juvenile observed on 3rd August 2019. On 2nd and 3rd August 2019, the presences of the already spotted adults were also reconfirmed. The different individuals were compared by photo identification.

The other observation concerns the finding of many individuals in the Province of Cuneo. Another author (R.G.) found more than 20 adult individuals, five of which with regenerated tails, on the walls of a private house and of an adjacent warehouse (outside and inside) situated on Provincial Road 130, Valle Talloria, Cuneo, 210 m a.s.l., approximate coordinates: 44°391”N, 7°5917”E (Figs. 3, 4). The geckos were spotted on 7th June 2019 from about 9.00 pm to 11.00 pm (data reported even on iNaturalist), after that the owner of the property reported seeing them certainly for more than a year. Based on his personal experience, no other observations are known for Valle Talloria up to date.

DISCUSSIONS AND CONCLUSIONS

Excluding the populations described here, *H. turcicus* has been reported for Piedmont solely on the basis of two single individuals through the Ornitho web portal (specifically, an individual in October 2018 in Turin and one in October 2019 in Settimo Torinese).

Since the Turkish Gecko is a thermophilic species, its acclimatization in a new area could depend on the trend of the mean annual temperatures, specifically of the minimum ones (Pegorini &



Figures 1-4. *Hemidactylus turcicus* from the Piedmont populations (Italy): adult with intact tail (Fig. 1) and young (Fig. 2) from Turin; adult with intact tail (Fig. 3) and adult with regenerated tail (Fig. 4) from Valle Talloria, Cuneo. Photos: D. Raimondi (Figs. 1, 2) and R. Ghiglia (Figs. 3, 4).

Ghezzi, 2019). Concerning Piedmont, the analysis of mean annual temperature anomalies relative to 1958-2015, with reference to 1971-2000, shows a long line of positive values from 1986 onwards and the total estimated rise is about 1 °C (Arpa Piemonte). The mean thermal anomalies of the last four years from the same reference value are positive too: +1.3 °C (2016); +1.5 °C (2017); +1.6 °C (2018); +1.5 °C (2019). (Arpa Piemonte, Il Clima in Piemonte, 2016; 2017; 2018; 2019). Always with reference to 1971-2000, positive tendencies can be observed even in the trends of maximum and minimum daily temperatures relative to 1958-2015, with rises of +2 °C and +1.5 °C respectively (Arpa Piemonte). For the following years, these are the TMAX/TMIN pairs of values: +1.8 °C/+0.8 °C (2016); +2.3 °C/+0.8 °C (2017); +1.9 °C/+1.4 °C (2018); +1.8 °C/+1.2 °C (2019) (Arpa Piemonte, Il Clima in Piemonte, 2016; 2017; 2018; 2019).

Moreover, urban contexts can have much higher temperatures than rural ones: for example, the temperature differential of mean annual temperatures relative to 2002-2016 between the urban and the rural areas of Turin is +1.7 °C (Istat, 2018). This could positively affect especially the population observed in the city. In any case, the two populations have been observed on the walls of anthropic structures and even within them: a context where to find suitable parameters, also to compensate for any climatic unsuitability of the territory in which they settled.

In conclusion, in line with current climate changes, even Piedmont is subject to a rise of temperatures that could have played a role in the acclimatization of the Turkish Gecko in this region after accidental human transports. Further investigation is needed to establish the actual expansion of this species in Piedmont, also looking for the possible presence of individuals settled far from anthropic structures.

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Endemism of Sphinx Moth (Lepidoptera Sphingidae) in the Agroecosystem of Bacusanon, Pangantucan, Bukidnon, Philippines

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ABSTRACT Sphinx moths, or also known as hawkmoths, clearwing moths or hummingbird moths, are nocturnal insects which plays an essential role in the stability of terrestrial ecosystems. There are 117 species of sphinx moth occurring in the Philippines of which 62 species can be found in Mindanao Island. The light trap sampling technique was employed to successfuly collect crepuscular sphinx moths species. This paper aimed to provide information on species composition, endemism, local status and morphological data of sphinx moths in Bacusanon, Pangantucan, Bukidnon. A total of 25 individuals of sphinx moths were documented, which belongs to 9 genera of 13 species namely *Acherontia lachesis*, *Acosmeryx anceus subdentata*, *Agrius convolvuli*, *Ambulyx johnsoni*, *Amplypterus panopus mindanaoensis*, *Amplypterus panopus panopus*, *Hippotion boerhaviae*, *Hippotion rosetta*, *Marumba ambroinicus luzoni, Psilogramma menephron*, *Theretra clotho*, *Theretra nessus* and *Theretra oldenlandiae*. Of the 13 species, the local status revealed that 11 species are common, 1 species rare and 1 species uncommon. Twelve (12) or 92.3% species are endemic to the Philippines.

KEY WORDS Lepidoptera; Mindanao; Moth; Sphinx; Philippines.

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INTRODUCTION

Sphinx moth is also known as hawkmoths, clearwing moths and hummingbird moth. Hawkmoths plays a crucial role on the stability of terrestrial ecosystems (Primo et al., 2013). They are important nocturnal pollinators (Mohagan et al., 2018; Chiquetto et al., 2018)) in most of the biodiverse regions on the earth and an ideal organism exploring pollinator niches (Johnson et al., 2016). They also served as prey for other higher trophic levels like birds and bats.

With over 160,000 described species (Kawahara & Breinholt, 2014; Tujuba et al., 2019) of Lepidoptera, they are thought to be the second largest order in class insecta (Tujuba et al., 2019), with most of them being biomass converters and pollinators (Mohagan et al., 2019). Sphinx moth belongs to the family Sphingidae comprising about 1,450 species all over the world (Singh, 2017) and 117 species are occuring in the Philippines, of which 24 are Philippine endemic species and 10 are Philippine endemic subspecies that are widely distributed on the archipelago with some Asian species (Hogenes & Treadaway, 1998). And like all other insects, sphinx moths have thorax, abdomen and wings which are densely covered with scales. They are distinguished among others because of their rapid flying ability, which can reach up to 40km/hr (Akkuzu et al., 2007), bullet-shaped bodies with long, narrow forewings and shorter hindwings and having a long proboscis is the hallmark of this family (Messenger, 1997; Miller, 1997).

As cited in the report of Rafi et al. (2014), like all other organism, most Sphingidae are highly specialized due to the fact that each species live in accordance with the type of their habitat or environmental status like the availability of their suitable host plants as well as environmental factors like altitude, rainfall, sunshine and temperature. Some of the species of hawkmoths are benign in nature and some species possess economic importance.

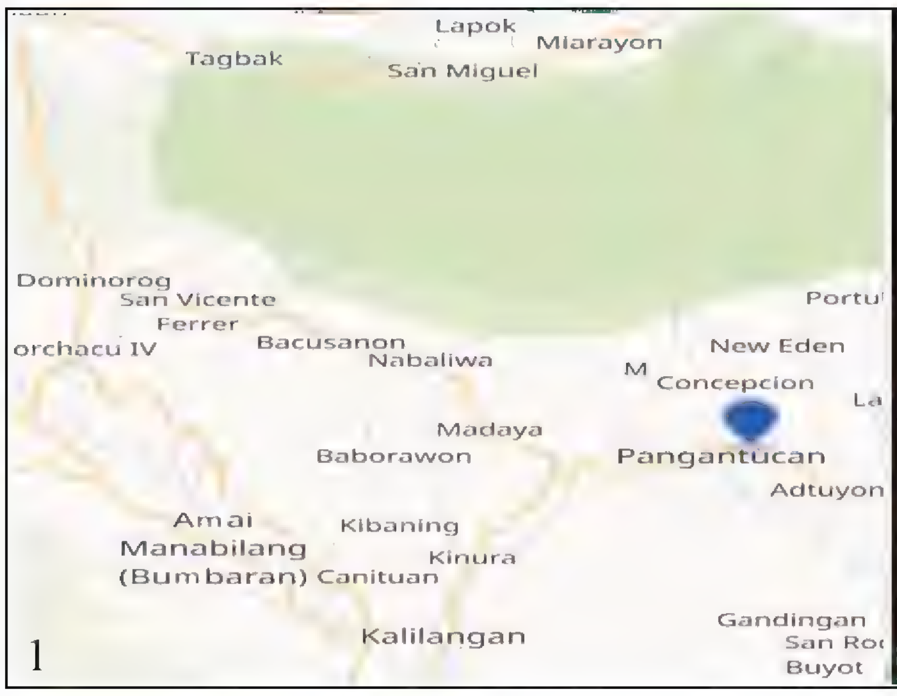
MATERIAL AND METHODS

The study was conducted in Barangay Bacusanon, Pangantucan, Bukidnon. The barangay clearance and farm owner permission were secured and approved for light trap sampling. The light trap was set in the agroecosystem facing Mt. Kalatungan. The farm was planted with corn, coffee, rice and bananas but some of the original plants were retained. So it is still a mix forest. The water body is just around 5 km and the water is clear. It serves as the water source for drinking and bathing for the community. The original trees present are Falcata, Mosese, Dapdap and Tambuyog. The temperature range from 15°C to 19°C and the weather was foggy with starry night. The light trap (Fig. 1) was used on to collect sphinx moths species. Light traps were set for ten hours from 6 PM to 4 AM in the morning. We used 500 watts, 12 voltage tungsten bulb powered from portable generator with the source power of 220AC. A 3m x 3m white cloth was established where night flying insects. The samples were collected and photographed. Identification of the collected sphinx moths species was based on morphological structures and using Hogenes & Treadaway (1998) checklist at Central Mindanao University Museum Zoology Section.

RESULTS AND DISCUSSION

The light trap sampling at Bacusanon farm yielded abundant moths despite cold temperatures (15°C–19°C). A total of 25 individuals of sphinx moths which belong to 9 genera and 13 species were documented (see Table 1, Figs. 3–15). The ecological status of sphinx moths based on checklist of Hogenes & Treadaway (1998) revealed they were all endemic taxa except *A. panopus panopus mindanaoensis* which is widespread in Cebu, Jolo, Leyte, Mindoro, Mindanao, Negros, Panay, Polilio Island, Romblon, Samar, and Sibuyan. The local status of the collected sphinx moths species revealed that all are common species except 1 uncommon species (*H. boerhaviae*); only *A. panopus panopus* is rare species.

During sampling period, the temperature was



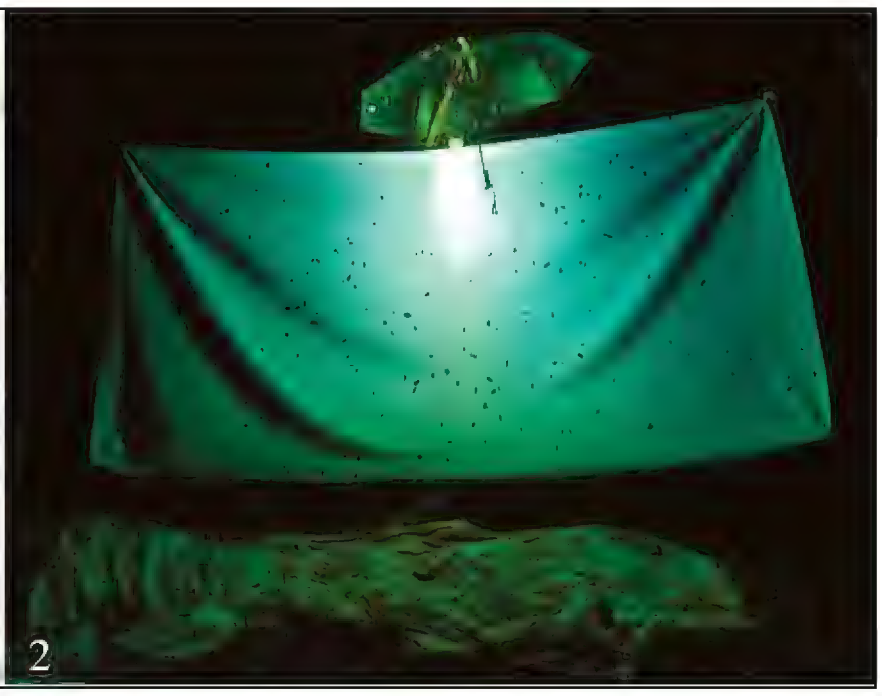


Figure 1. Map of Bacusanon, Pangantucan, Bukidnon. Figure 2. Light Trapping Technique.

cold and drizzle was observed. Fry & Waring (1996) stated that light sampling technique is less productive when it is cold and wet. Local conditions such as wind speed, temperature, humidity and the amount of time that the trap is operated are one of the most important factors to consider in collecting sphinx moth species (Jonason et al., 2014). Areas with habitat disturbance as well as human interactions with the environment could also affect the hawkmoth faunal composition (Chiquetto et al., 2018).

Sphinx moths varied in their sizes. Their antennae were proportional to their body sizes ranging from 0.9–2.3 cm, hook ranged from 0.1–0.2 cm and eyes ranged from 0.2–0.6 cm. The thorax consists of three segments namely; prothorax ranging 0.3–1.0 cm, mesothorax ranging from 0.2–0.5 cm and metathorax ranging from 0.2-0.5 cm. They all vary in color. Forewings ranged from 2.1–7.4 cm while hindwings ranged from 1.2–4.0 cm. Legs measured 1.2–3.8 cm, while eight segments ranged from 1.4–3.7 cm. Spine ranged from

Species	N. of species collected	Endemism	Distribution	Local Status
Acherontia lachesis (Fabricius, 1798)	1	Endemic	Bal Ceb, Ley, Luz, Mar, Mdo, Mno, Neg, Pal, Pan, Pol, Sam	Common
Acosmeryx anceus subdentata (Rothschild & Jordan, 1903)	1	Endemic	Bal, Boh, Cal, Ceb, Din, Jol, Ley, Luz, Mar, Mdo, Mno, Neg, Pal, Pan, Sam, Sga, Stu, Taw	Common
Agrius convolvuli (Linnaeus, 1758)	1	Endemic	Bal, Boh, Cal, Ceb, CmM, Din, Jol, Ley, Luz, Mdo, Mno, Neg, Pal, Pan, Sam, Sga Siq	Common
Ambulyx johnsoni (Clark, 1917)	3	Endemic	Ceb, Ley, Luz, Mar, Mdo, Mno, Neg, Pan, Sam, Siq	Common
Amplypterus panopus mindanaoensis (Inoue, 1996)	3		Ceb, Jol, Ley, Mdo, Mno, Neg, Pan, Pol, Rom, Sam, Sib	Common
Amplypterus panopus panopus (Cramer, 1779)	2	Endemic	Bon, Pal	Rare
Hippotion boerhaviae (Fabricius, 1775)	3	Endemic	Jol, Ley, Luz, Mno, Neg, Pal, Pan, Sib	Uncommon
Hippotion rosetta (Swinhoe, 1892)	1	Endemic	Bal, Boh, Bon, Ceb, Jol, Ley, Luz, Mar, Mdo, Mno, Neg, Pal, Pan, Sga, Siq, Stu, Taw	Common
Marumba ambroinicus luzoni (Clark, 1935)	1	Endemic	Bab, Boh, Ceb, Din, Jol, Ley, Luz Mar, Mdo, Mno, Neg, Pan, Sam, Sib, Siq	Common
Psilogramma menephron (Cramer, 1780)	2	Endemic	Bal, Boh, Bon,Ceb, Dum, Jol, Ley, Luz, Mas, Mdo, Mno, Neg, Pal, Pan, Sam, Siq, Stu, Taw	Common
Theretra clotho (Drury, 1773)	1	Endemic	Bal, Boh, Bon, Cal, Ceb, Joy, Ley, Luz, Mdo, Mno, Neg, Pal, Pan, Sam, Sib, Siq, Stu, Taw	Common
Theretra nessus (Drury, 1773)	5	Endemic	Bal, Boh, Cal, Cat, Ceb, Din, Jol, Ley, Luz, Mar, Mas, Mdo, Mno, Neg, Pal, Pan, Sam, Sib Siq, Stu	Common
Theretra oldenlandiae (Fabricius, 1775)	1	Endemic	Bal, Boh, Ceb Jol, Ley, Luz, Mdo, Mno, Neg, Pal, Pan, Pao, Sam, Sib, Siq, Taw	Common

Legend:
Bab- Babuyanes
Bal- Balabac
Boh- Bohol
Bon- Bongao
Cal- Calamian
Cat- Catanduanes
Ceb- Cebu
CmM- Camiguin de Luzon
Din- Dinagat
Pao-Panaon
Dum- Dumaran
Ley- Leyte
Luz- Luzon
Mar- Marinduque
Mas- Masbate
Mdo- Mondoro
Mno- Mindanao
Neg- Negros
Pao-Panaon
Pal- Palawan
Pan- Panay
Pol- Polilio Island
Rom- Romblon
Sam- Samar
Sga- Sarangani
Sib- Sibuyan
Siq- Siquijor
Stu- Sibutuc
Jol- Jolo

Table 1. Species Composition, Endemism, Distribution and Local Status of Sphinx Moths in Bacusanon, Pangantucan, Bukidnon.

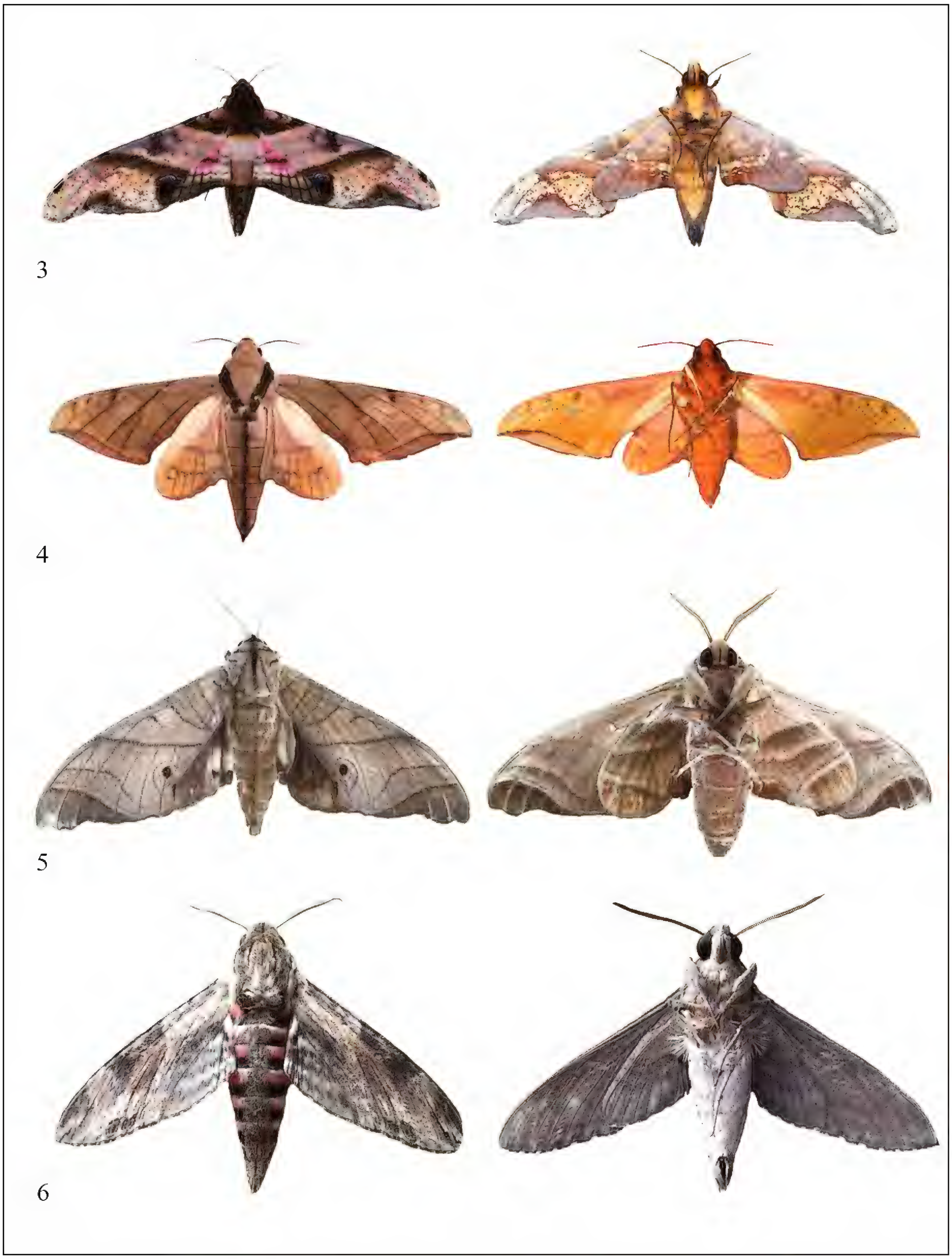
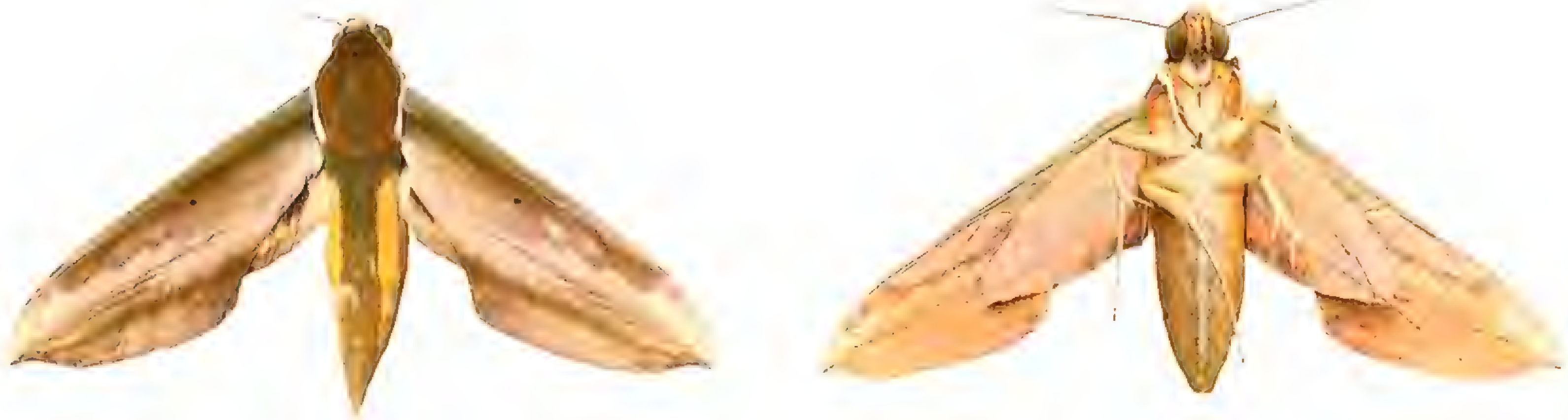


Figure 3. *Amplypterus panopus mindanaoensis* (Inoue, 1996) dorsal and ventral view. Figure 4. *Ambulyx johnsoni* (Clark, 1917) dorsal and ventral view. Figure 5. *Marumba ambroinicus luzoni* (Clark, 1935) dorsal and ventral view. Figure 6. *Agrius convolvuli* (Linnaeus, 1758) dorsal and ventral view.



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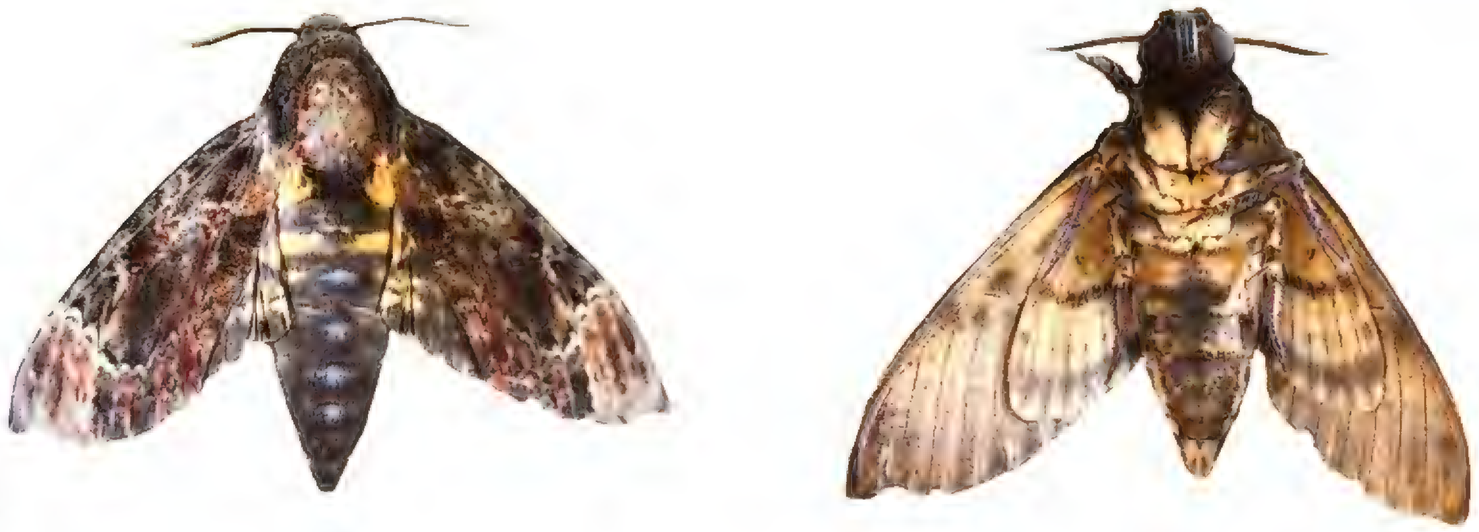

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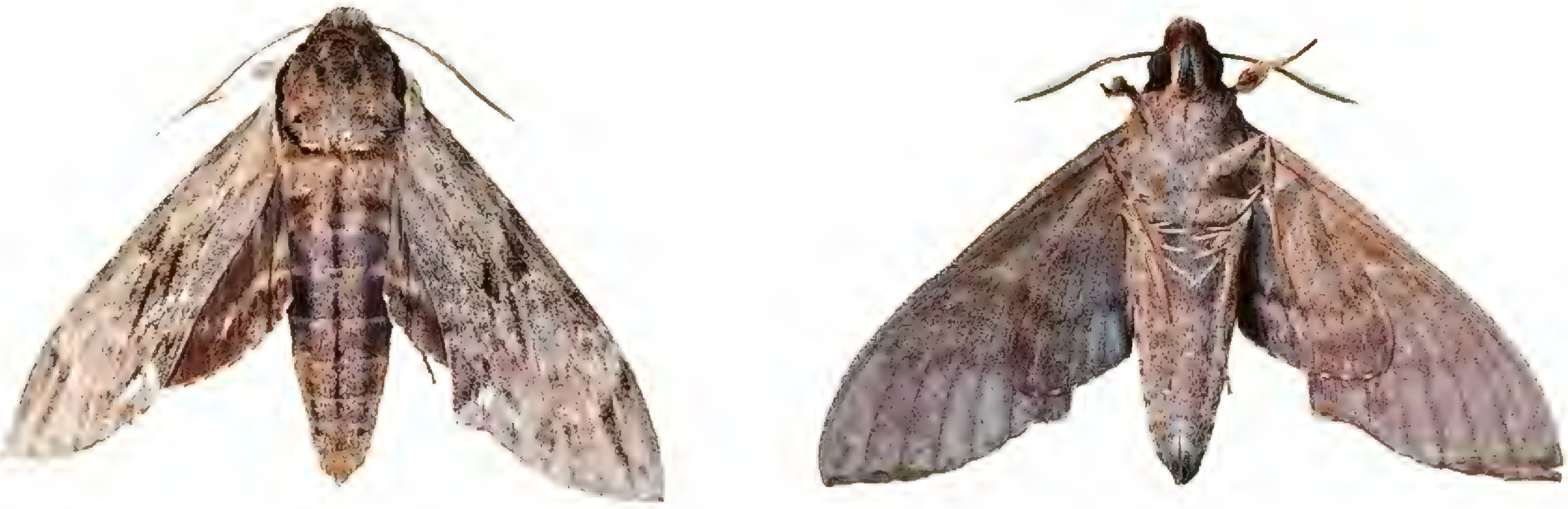

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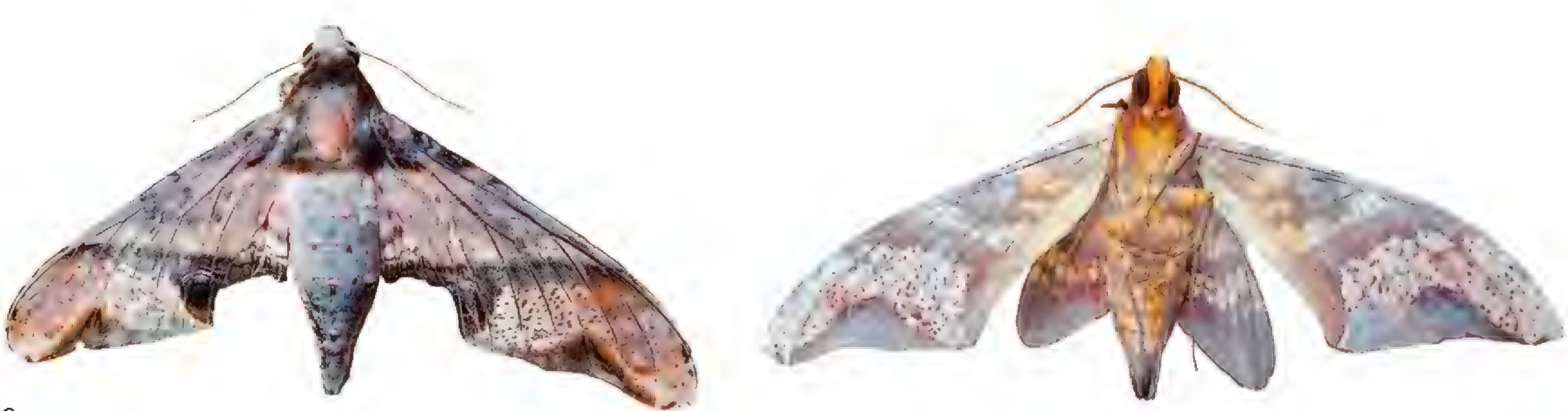

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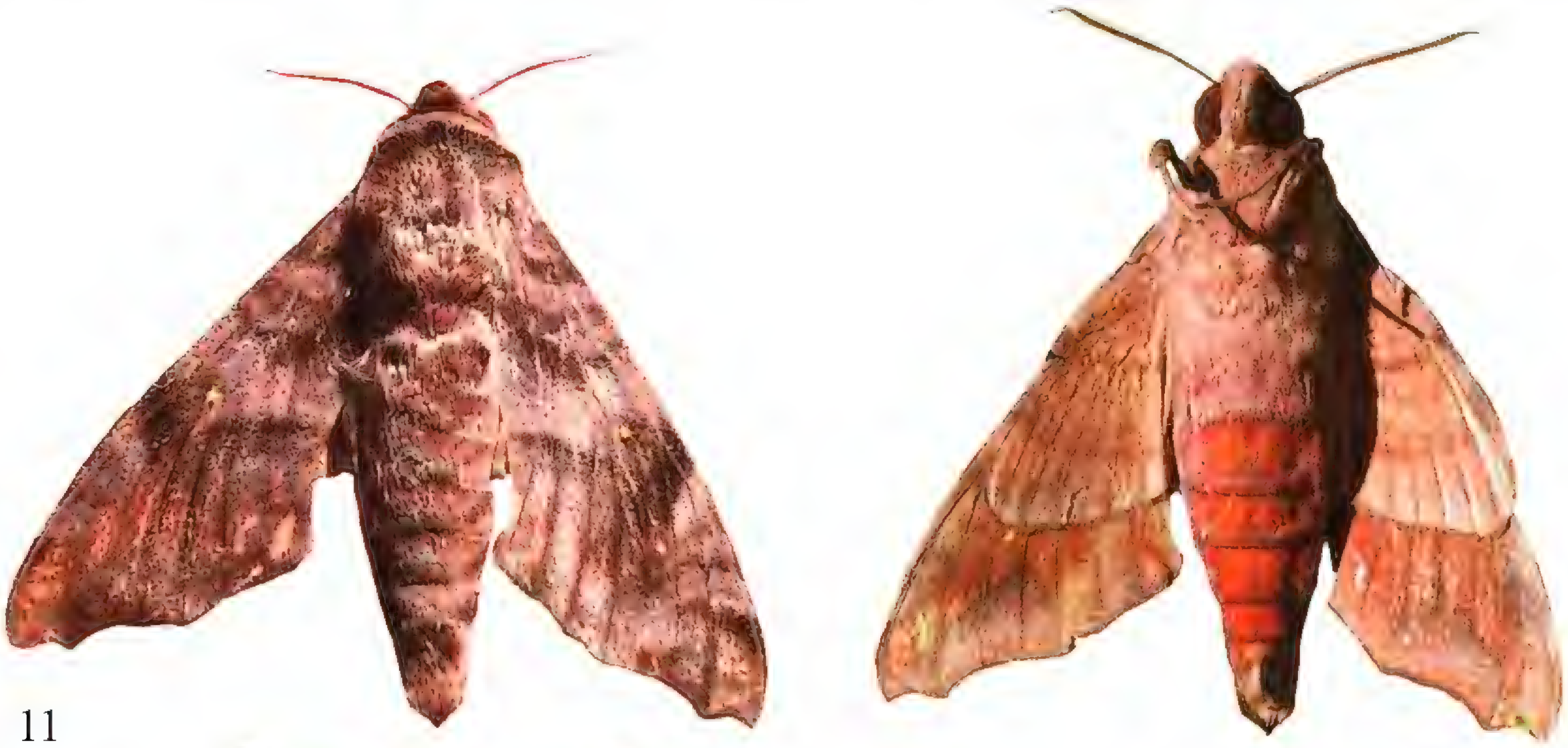
Figure 7. *Theretra nessus* (Drury, 1773) dorsal and ventral view. Figure 8. *Acherontia lachesis* (Fabricius, 1798) dorsal and ventral view. Figure 9. *Psilogramma menephron* (Cramer, 1780) dorsal and ventral view. Figure 10. *Amplypterus panopus panopus* (Cramer, 1779) dorsal and ventral view.



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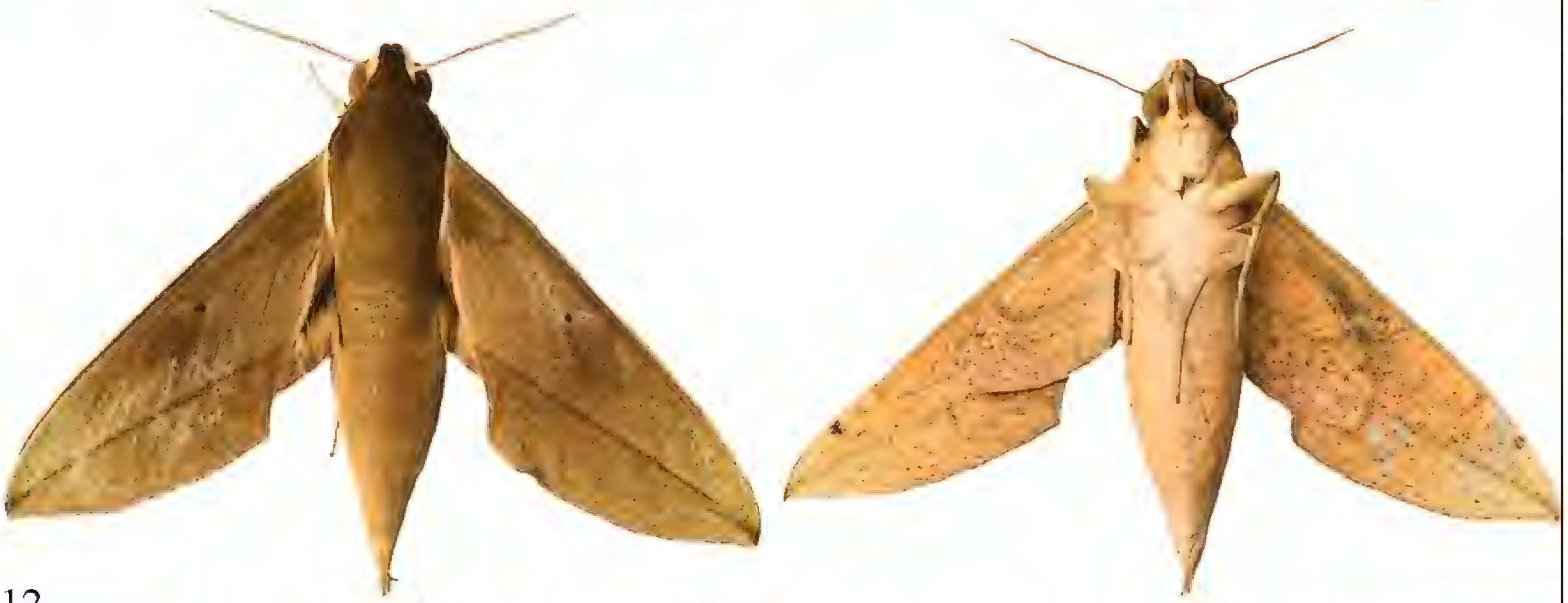

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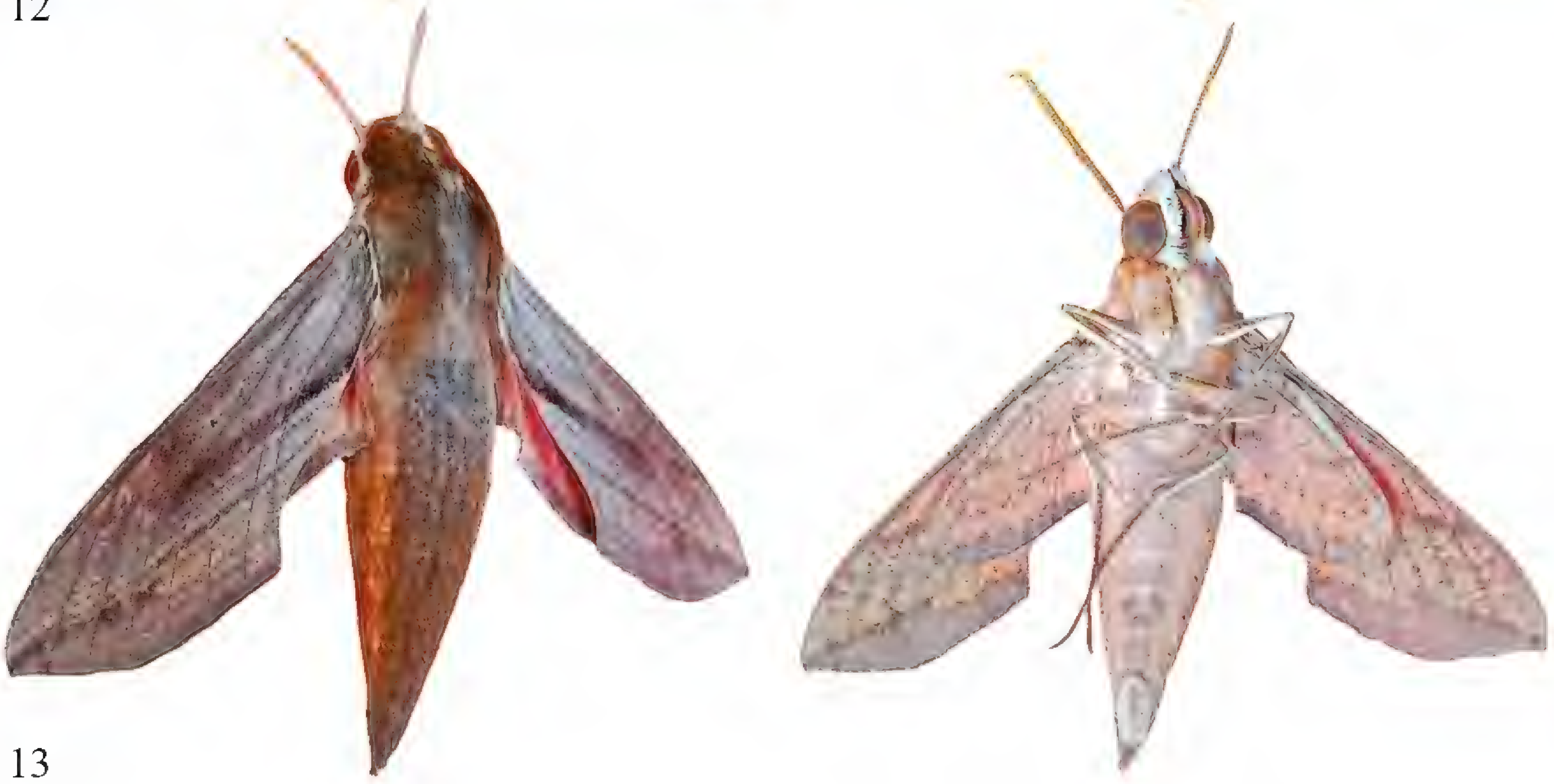

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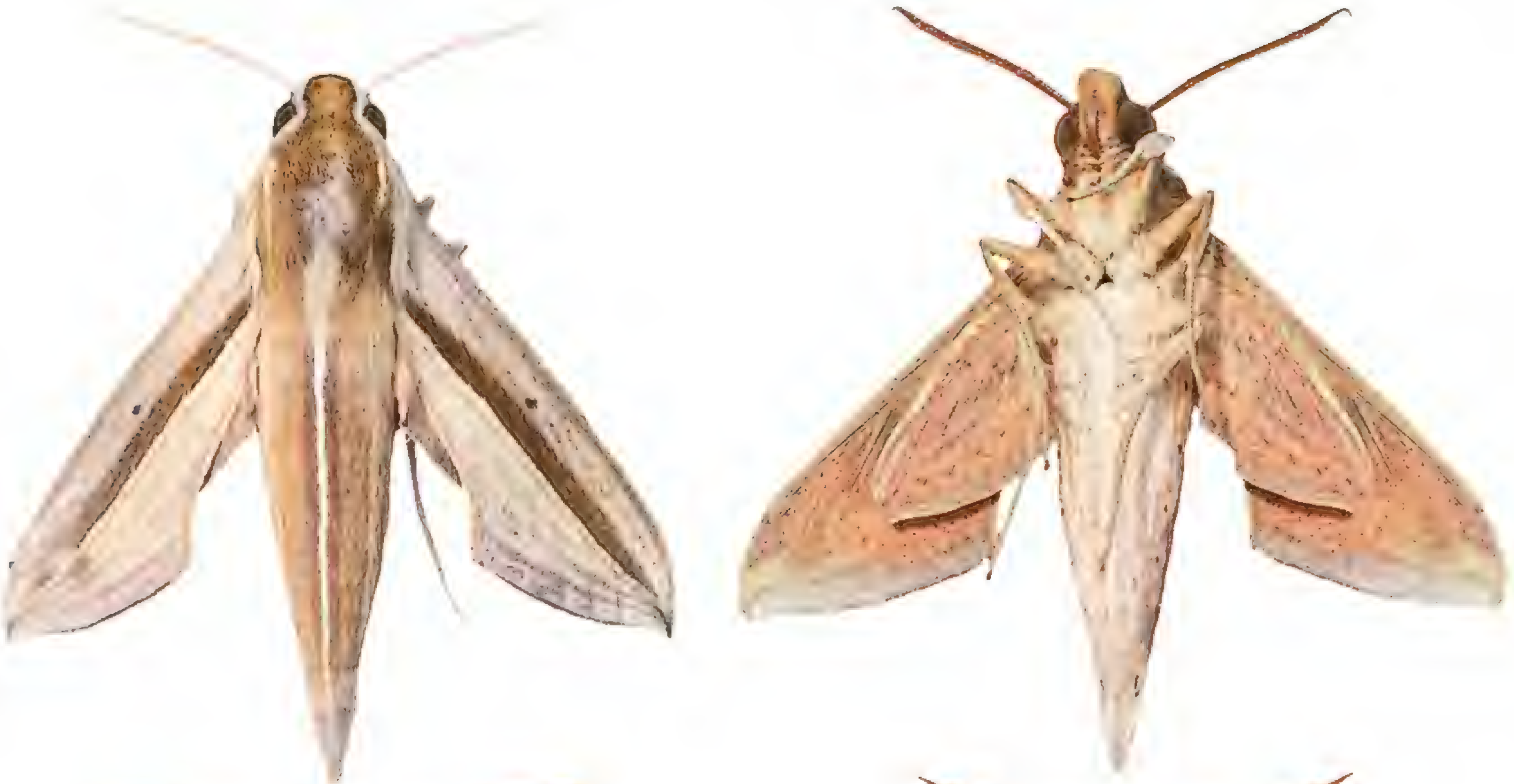
Figure 11. *Acosmeryx anceus subdentata* (Rothschild & Jordan, 1903) dorsal and ventral view. Figure 12. *Theretra clotho* (Drury, 1773) dorsal and ventral view. Figure 13. *Hippotion boerhaviae* (Fabricius, 1775) dorsal and ventral view.



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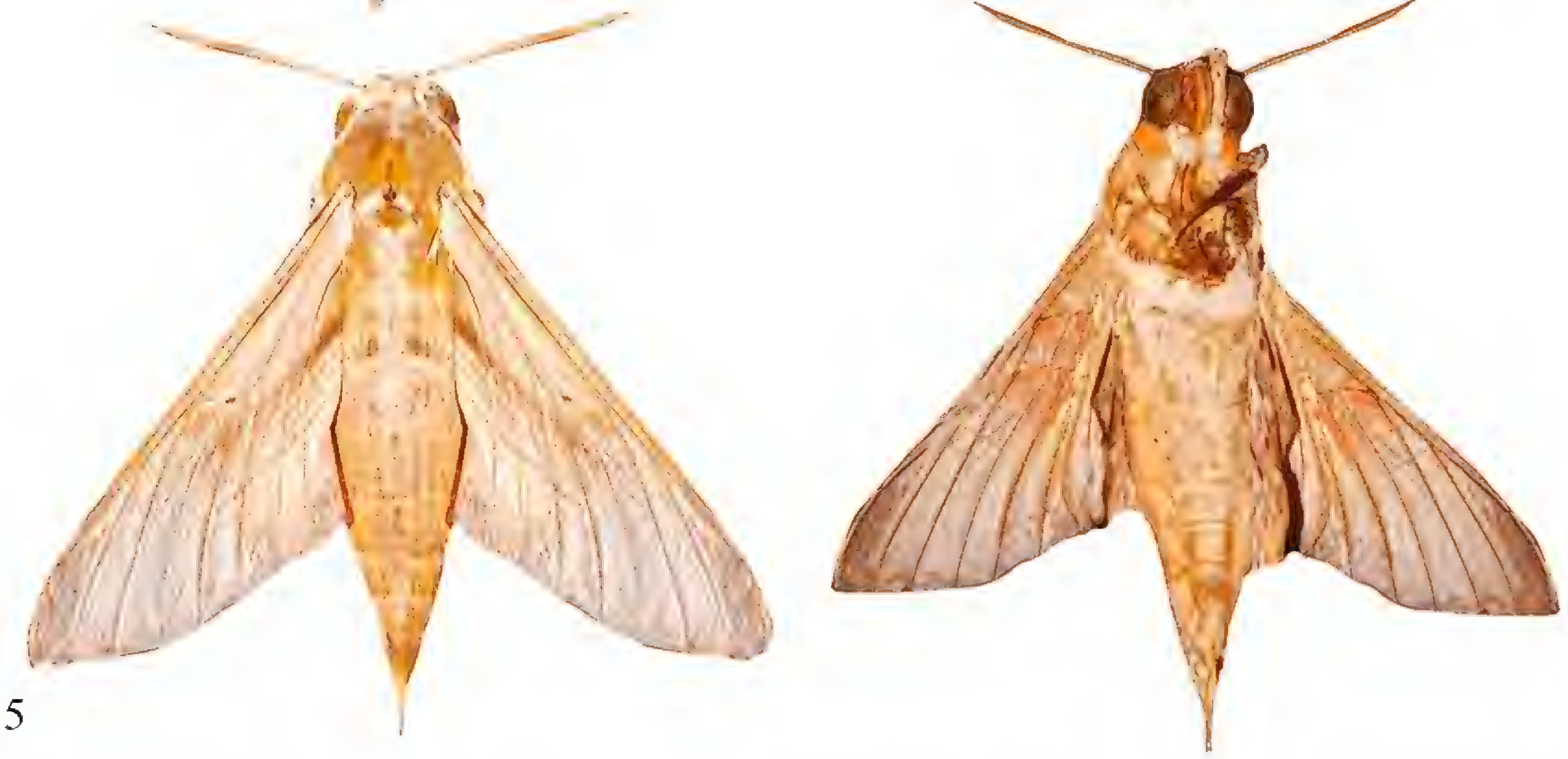

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Figure 14. *Theretra oldenlandiae* (Fabricius, 1775) dorsal and ventral view.
Figure 15. *Hippotion rosetta* (Swinhoe, 1892) dorsal and ventral view.

0.1–0.5 cm, while wingspread ranged from 2.6–9.2 cm. It was observed that availability of food and water affects the growth of sphingid moths. Sphinx moths are also fast flyers. Light trapping technique was a very useful method on sampling night flying fauna. They are nocturnal and they are attracted to light. The species of sphingid moths varied on their color and structure. They have narrow forewings and shorter hindwings. Eyespots are present on the forewings and hindwings of some species. Eyespots may resemble eyes and could cause smaller predators to believe them to be the head of larger animal (Stevens, 2005).

CONCLUSIONS

A total of 12 endemic species (92.3%) out of 13 recorded species in Bacusanon, Pangantucan, Bukidnon, Philippines were documented, namely: *Acherontia lachesis*, *Acosmeryx anceus subdentata*, *Agrius convolvuli*, *Ambulyx johnsoni*, *Amplypterus panopus mindanaoensis*, *Amplypterus panopus panopus*, *Hippotion boerhaviae*, *Hippotion rosetta*, *Marumba ambroinicus luzoni*, *Psilogramma menephron*, *Theretra clotho*, *Theretra nessus*, and *Theretra oldenlandiae*. The local status revealed 11 common species and 1 rare species, the *A. panopus*

panopus. Morphological characteristics are useful in identifying the sphinx moths up to species level.

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Seasonality of *Edmundsella pedata* (Montagu, 1816) (Nudibranchia Flabellinidae) along the Ionian coasts of Sicily (Central Mediterranean Sea)

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ABSTRACT This work explores the seasonality of *Edmundsella pedata* (Montagu, 1816) (Nudibranchia Flabellinidae) in three sites located along the central-eastern coast of Sicily (Italy). Since most of aeolidacean nudibranchs are subannual, it has been hypothesized that *E. pedata* is also a subannual species with several generations per year. Therefore, *E. pedata*'s trend was studied in the three study areas throughout three years (from 2017 to 2019). Through data collection, it was observed that this nudibranch is an opportunistic and subannual species, which in natural habitats, has an increase in autumn, a peak in winter and a decrease during spring and summer. Instead, in anthropized sites, it was not possible to define a real seasonality of *E. pedata*. In conclusion, throughout the three years, a strong increase in the number of *E. pedata* specimens in all study areas has been seen.

KEY WORDS Aeolidacea; *Edmundsella pedata*; Nudibranchia; seasonality; Sicily.

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INTRODUCTION

Edmundsella pedata (Montagu, 1816) (Figs. 1-4) is a nudibranch of the family Flabellinidae Bergh, 1889, which includes 121 species with a worldwide distribution. In particular, *E. pedata* is a common species along the coasts of eastern Atlantic and Mediterranean Sea (Barletta & Melone, 1976; Thompson & Brown, 1984; Malaquias et al., 2014; Öztürk et al., 2014; Trainito & Doneddu, 2014).

This nudibranch was found in several habitats such as coralligenous, zosteraceae meadows, sandy bottoms, coastal seaweeds, *Peyssonellia polymorpha* (Zanardini) F. Schmitz bottoms, among sublittoral hydrozoans, both on illuminated and shaded rocky walls, rarely on Clorophyta and sponges (Barletta & Melone, 1976). Moreover, *E. pedata* was found also on bryozoans as *Flustra foliacea* (Linnaeus, 1758) and on the sea anemone *Sagartia elegans* (Dalyell, 1848) (McDonald & Nybakken, 1997). According to Clark (1975) and Todd (1981), most of the aeolidacea are considered subannual species with regard to their life cycle. Indeed, these species are ephemeral, with several generations during the year and a r-strategy, showing large fluctuations in abundance during a short time. The rapid growth in size of these species is related to the presence of cerata, which are an adaptation permitting increased rates of assimilation and metabolism (Clark, 1975). In addition, the cerata provide an increase in both respiratory and digestive surface area. These characteristics allow aeolidaceans to feed on transient food which appears early in the microsuccesion of fouling communities (Clark, 1975).

Considering that *E. pedata* feeds on hydrozoans (McDonald & Nybakken, 1997), undergoes wide fluctuations and breeds at different times of the year, it might be assumed that this species is subannual. For that reason, *E. pedata* could be an opportunistic species that tolerates different environmental conditions. The aim of this work is to gain knowledge on the seasonality of this species in the Ionian coasts of Sicily.

MATERIAL AND METHODS

This study was carried out during three years (from 2017 to 2019) in five sites of the central-eastern coast of Sicily (Ionian Sea). Geologically, this area consists of subvolcanic rocks: columnar basalts and effusive submarine products forming fields of pillow lavas (Sciuto et al., 2017). The whole area is characterized by a belt of rocks, up a few meters in size, which are accumulated along the coast and at the base of shallow cliffs (Sciuto et al., 2017). Five stations were studied: two sites, Ognina (37°31’50.4”N, 15°07’10.8”E) and Bellatrix (37°32’03.2”N, 15°07’35.2”E) are located in the municipality of Catania; while three sites, Santa Maria La Scala (37°36’46.5”N, 15°10’31.4”E), Acque Fredde (37°38’15.7”N, 15°10’52.1”E) and Scalo Pennisi (37°38’23.2”N, 15°11’04.6”E), are located in the municipality of Acireale (Fig. 5). These sites were chosen considering different environmental conditions. Indeed, the Ognina and Bellatrix stations are strongly anthropized and, since they are located near each other and have similar ecological conditions, were considered as a single site, listed from now on as “Catania”. Moreover, the same reasoning was made for Acque Fredde and Scalo Pennisi, which are situated near each other and are both least impacted sites, thus, are listed from now on as “Santa Tecla”. The station of Santa Maria La Scala was considered individually because is far from the other sites and has intermediate conditions between those of Catania and Santa Tecla. Data were collected through underwater visual census with scuba diving. In particular, a total of 224 dives was realized: 74 in Santa Maria La Scala, 83 in Catania (Bellatrix and Ognina), 67 in Santa Tecla (Scalo Pennisi and Acque Fredde). Each scuba dive was carried out about from 9:00 to 11:30 a.m. For each site the same path was followed and specimens of *E. pedata* were photographed with an Olympus TG4 camera and counted in situ. The seasons were considered as follows: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November). Through data collection, the demographic trend of *E. pedata* was assessed. In addition, for each station, specific density was evaluated as mean number of individuals/diving number per site. Using the Arcgis 10.3 software (ESRI® Software, USA), the different sampling areas were geo-referenced (Fig. 5). The experimental design adopted was completely randomized and replicated four times. Data were subjected to analysis of variance (ANOVA). Mean comparisons were performed according to Tukey Minimal Difference (MDS).

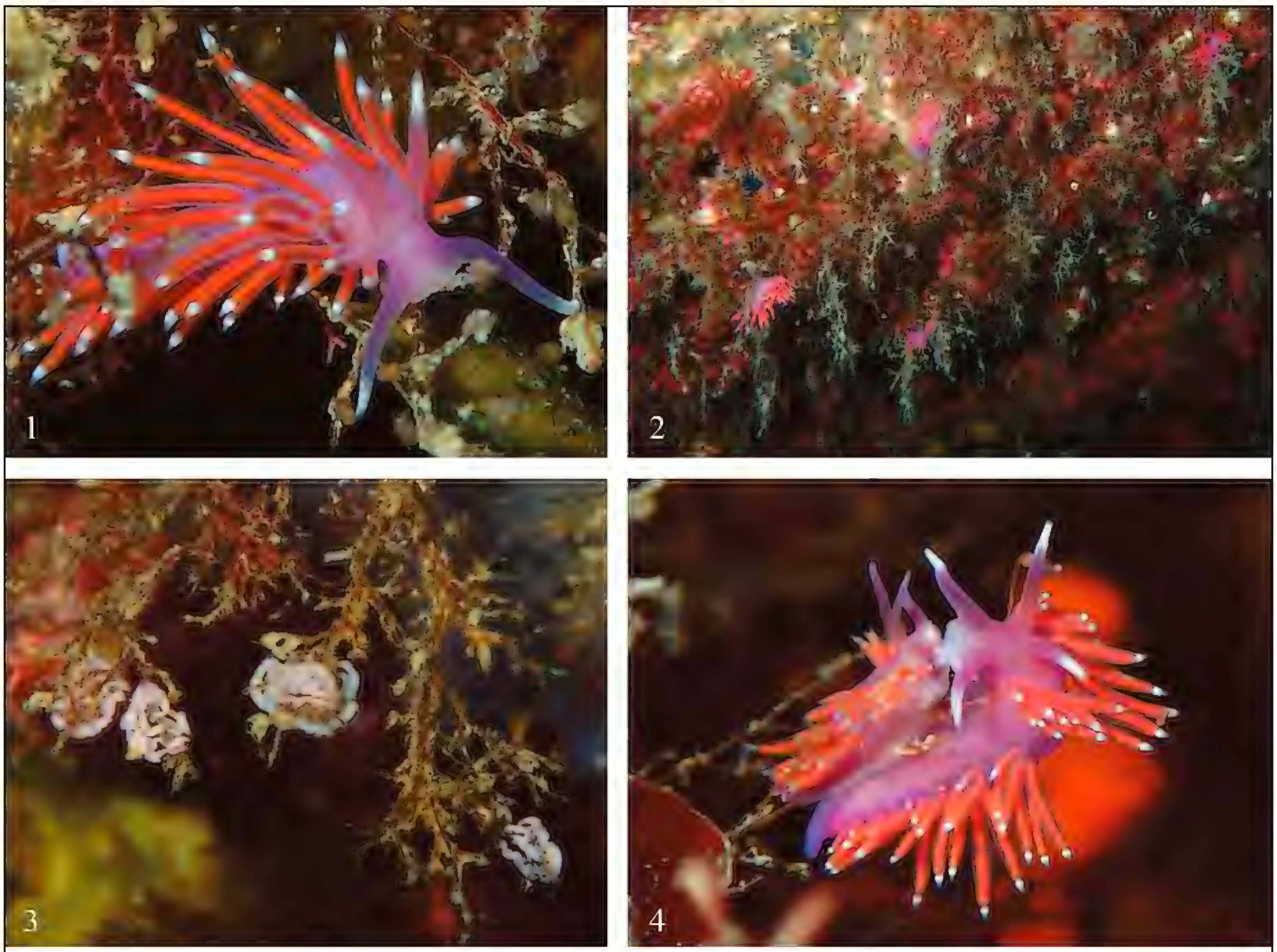
RESULTS

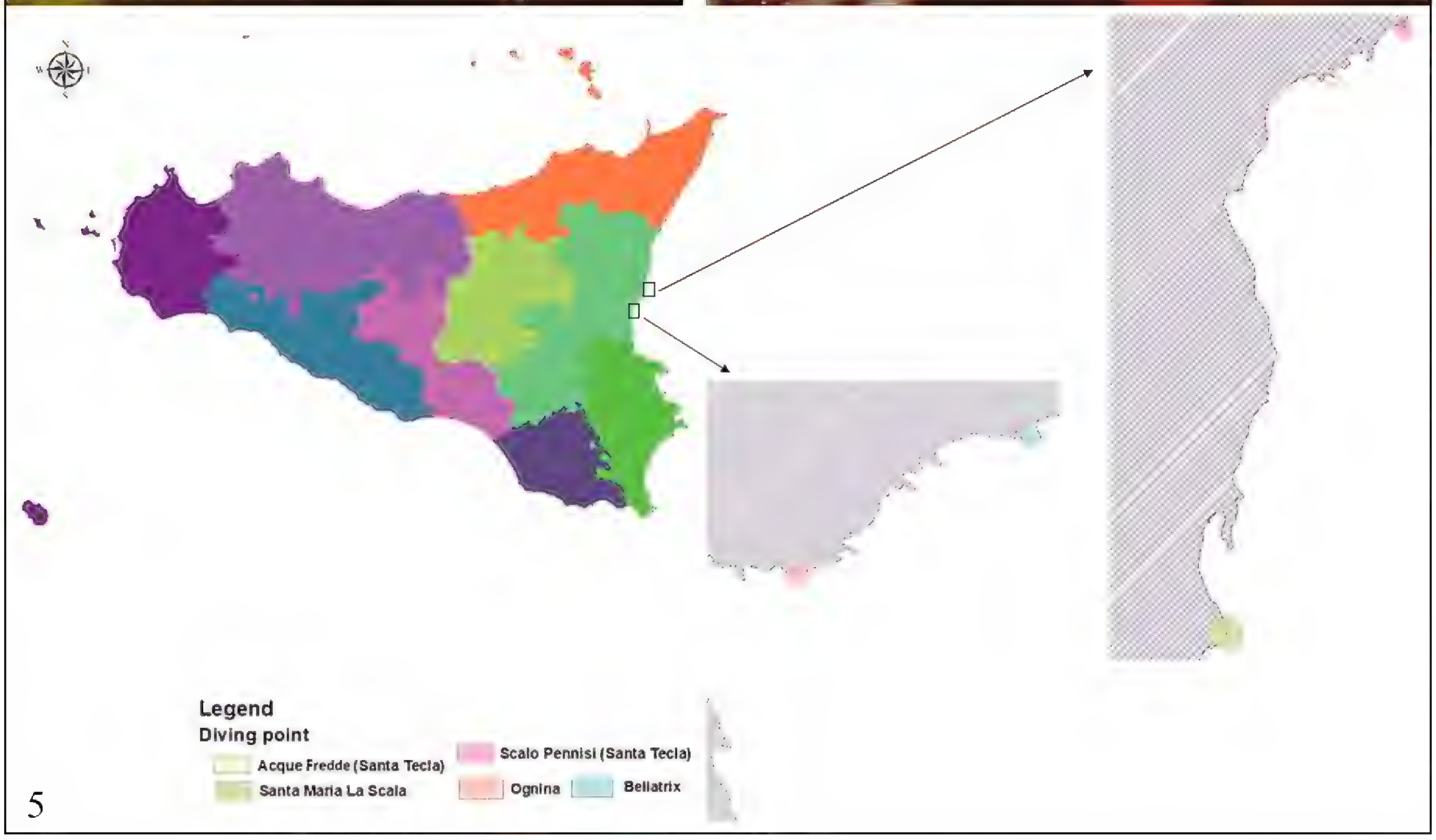
The results showed that *E. pedata* populations were significantly influenced by spatial (different sampling points) and temporal (different years) variations. In “Santa Tecla” station, the *E. pedata* populations showed a significantly demographic increasing, compared to the "Santa Maria la Scala" and “Catania” stations. The communities sampled in Santa Tecla were +56% ($p<0.01$) compared to those found in Santa Maria La Scala and +71.8% compared to those observed in Catania. During the three years’ trial, a demographic growing trend was observed in *E. pedata* populations. From 2017 to 2019, an increase in the population of +55% ($p<0.01$) was observed. No differences were observed between 2018-2019 (Fig. 6).

Santa Maria La Scala

In Santa Maria La Scala, the *E. pedata* populations, were significantly influenced by an interaction between seasonal and annual fluctuations (Fig. 7). Over the three years, the communities sampled showed a significantly peak during the winter season. On the contrary, in the other seasons, the observed populations were similar to each other. This trend did not show significant differences between 2017 and 2018.

In 2019 a significant season effect on the populations under study was observed; winter and spring

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Legend
Diving point
Acque Fredde (Santa Tecla)
Santa Maria La Scala
Scalo Pennisi (Santa Tecla)
Ognina
Bellatrix

Figures 1-4. *Edmundsella pedata* from Ionian coasts of Sicily. Fig. 1: lateral view of a *E. pedata* specimen. Fig. 2: *E. pedata* assemblages on *Eudendrium* colonies. Fig. 3: *E. pedata* eggs on *Eundendrium* sp. Fig. 4: two specimens before breeding (photos A. Lombardo). Figure 5. Territorial framework of the diving points.

were the seasons in which the communities showed the highest average number of organisms, while during the summer and autumn the number started to decline. In 2018 the populations showed lowest number of organisms. Comparing 2017 and 2018, the population had suffered a decrease equal to -21% ($p < 0.01$) (Fig. 7).

Santa Tecla

In Santa Tecla area, the *E. pedata* communities were significantly influenced by seasonal fluctuations (Figs. 8, 9). Winter and spring showed a significantly growing trend compared to autumn and summer. These two seasons showed a reduction in organisms' average number. We observed a reduction of 79.5% between winter and autumn, and a reduction of 87.9% ($p < 0.01$) between winter and summer (Fig. 8). During the three years of observation, the *E. pedata* communities showed a significantly demographic increase (from 2017 to 2019) of + 65.5% ($p < 0.05$) (Fig. 9).

Catania

Like in Santa Maria La Scala, in Catania too (Fig. 10) the *E. pedata* communities were significantly ($p < 0.05$) influenced by an interaction between seasonal and annual fluctuations. The average number of counted organisms was significantly different over the three years. Unlike the other sampling areas, the maximum number of *E. pedata* was observed during the spring (2018-2019) and during the summer (2017). In 2017 there was a similar growing trend between the winter, spring and autumn seasons. In summer 2018 we observed an absolute absence of *E. pedata* in the study area.

Between the spring of 2018 and 2019, an increasing average number of *E. pedata* was observed (+ 27%). The year 2019 showed the highest organisms' average number, despite the marked differences due to seasonality. Indeed, in autumn there was a decrease in communities of -90% compared to spring. In the three years of experimentation, autumn was the only season in which the species showed a significantly similar growing trend (Fig. 10).

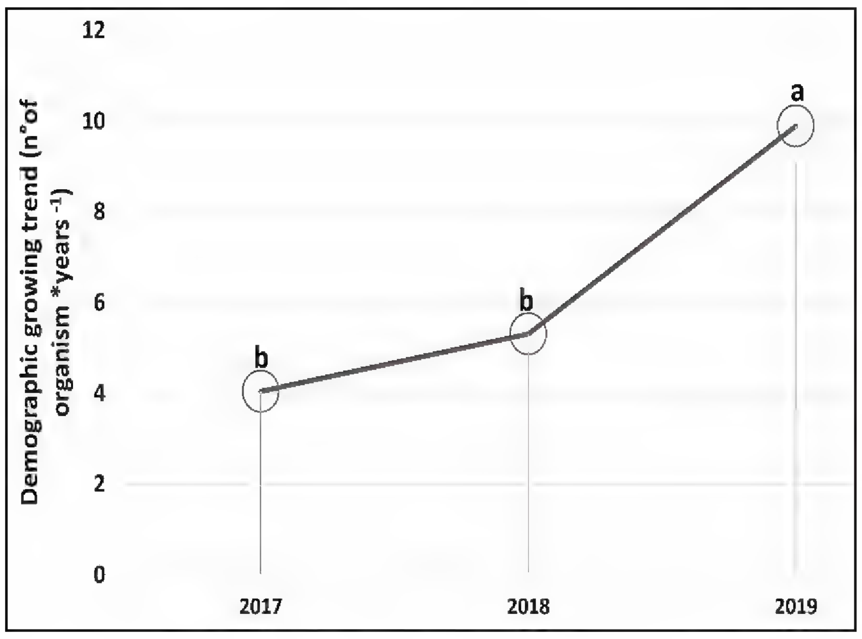

Figure 6. Demographic growing trend observed in a three-year cycle. Different letters indicate differences at $p < 0.01$.

DISCUSSIONS

In this work, *E. pedata*'s seasonality in the Ionian coasts of Sicily was explored. The majority of aeolidacean nudibranchs feed on hydrozoans and because there is an intimacy of this feeding relationship, a discussion of nudibranch's ecology must consider the biology of the food species. Todd (1981) highlighted that *E. pedata* is specialized in feeding on the hydrozoan *Ectopleura larynx* (Ellis & Solander, 1786). Moreover, according to Thompson & Brown (1984), juveniles of this species feed on calyptoblastic hydroids (Leptothecata), while adults eat gymnoblastic hydroids (Anthoathecata). Among the Leptothecata, *E. pedata* prey on *Abietinari aabietina* (Linnaeus, 1758), *Aglaophenia* spp., *Halecium halecinum* (Linnaeus, 1758), *Hydrallmania falcata* (Linnaeus, 1758), *Nemertesia* spp., *Obelia geniculata* (Linnaeus, 1758), *Sertularella gayi* (Lamouroux, 1821) (Barletta & Melone, 1976; Todd, 1981; Thompson & Brown, 1984; McDonald & Nybakken, 1997). Among the Anthoathecata, the prey are *Bougainvillia* spp., *Ectopleura larynx*, *Eudendrium racemosum* (Cavolini, 1785), *Eudendrium rameum* (Pallas, 1766), *Eudendrium ramosum* (Linnaeus, 1758), *Eudendrium glomeratum* Picard, 1952, *Garveia nutans* Wright, 1859, *Tubularia indivisa* Linnaeus, 1758 (Barletta & Melone, 1976; Todd, 1981; Schmekel & Portmann, 1982; Thompson & Brown, 1984; McDonald & Nybakken, 1997; Rudman, 1999 [In] Sea Slug Forum; Betti, 2011). During our data collection, the main assemblages of *E. pedata* were often found on *Eudendrium* facies

(Fig. 2). According to Betti (2011), *Eudendrium* (Ehrenberg, 1834) is the favorite source of food of this species and, in particular in the Adriatic Sea, *E. pedata* was often observed on *E. glomeratum*, a hydrozoan that lives in cold waters.

Generally, the hydrozoans are opportunistic and can tolerate different environmental conditions, as for example the species of the genera *Eudendrium* and *Obelia* Péron et Lesueur, 1810. Nevertheless, the temperature has an important role in the composition of hydroid population. In particular, *E. glomeratum* is a winter species that appears in mid-October, reaching the average height of colonies in January, and decreases until April (Boero, 1984). On the other hand, the life cycle of *Eudendrium racemosum* is opposite of *E. glomera*tum's one: the colonies become active from April and are fertile during the summer, but degenerate in autumn (Bavestrello et al., 2006). According to Azzini et al. (2003), in natural oligotrophic habitats, the main factors that establish the seasonality of *E. racemosum* are the temperature and the solar irradiance; while in harbors, in habitats with eutrophic waters and low competition, the life cycle of the colonies is strongly modified and this species is present during the whole year.

Considering these hydrozoans main characteristics, illustrated above, now *E. pedata*'s seasonality in three stations of the Ionian coast of Sicily is described in detail.

Santa Tecla

Santa Tecla is the area of this study in which there are the most stable environmental conditions. In fact, during the three year of observation, *E. pedata* had the same seasonal trend: large assemblages in winter, a starting decrease of the population in spring, the disappearance of almost all individuals in summer and then a new increase

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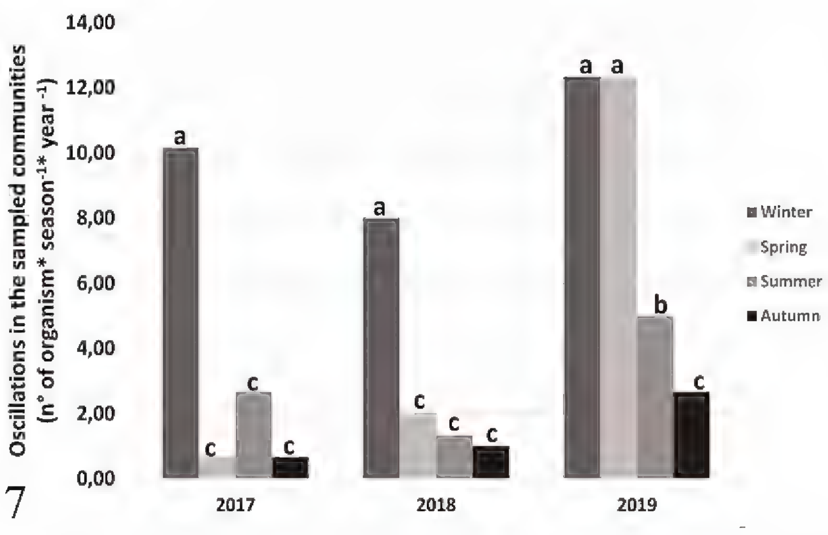

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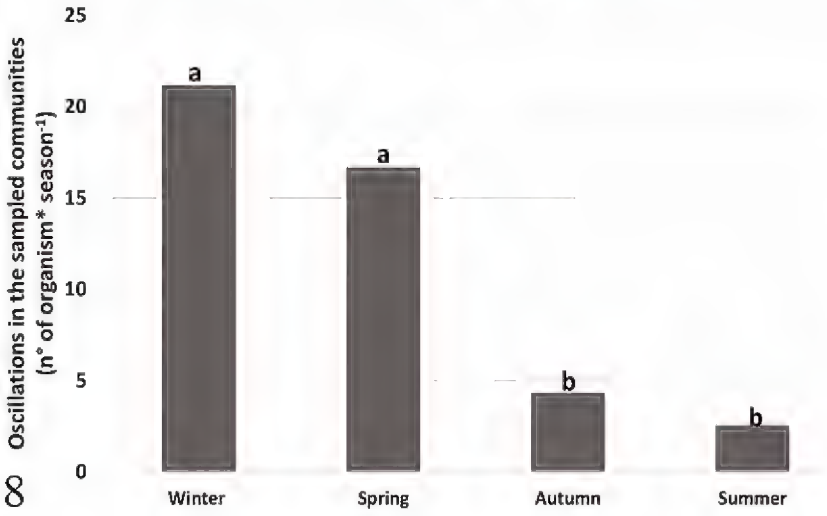

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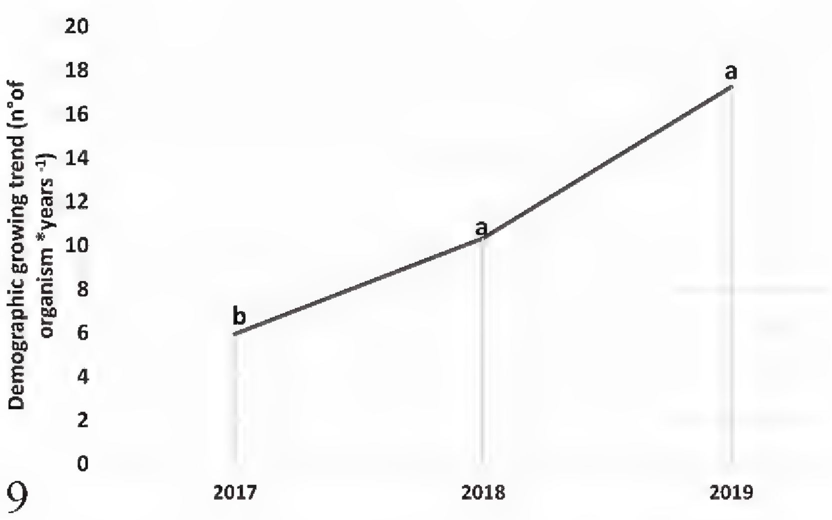

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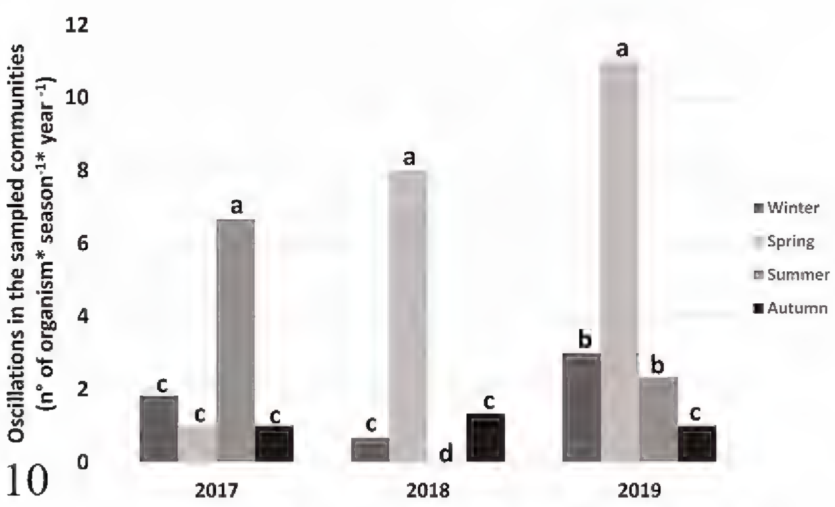

Figure 7. Oscillations in the sampled communities of Santa Maria La Scala during the three years' trial. Different letters indicate differences at p<0.01.

Figure 8. Organism number in Santa Tecla sampled communities influenced by seasonal fluctuations. Different letters indicate differences at p<0.01.

Figure 9. Demographic growing trend observed in a three-year cycle in Santa Tecla. Different letters indicate differences at p<0.05.

Figure 10. Oscillations in the sampled communities of Catania during the three years' trial. Different letters indicate differences at p<0.05.

in autumn. The stability of the *E. pedata*'s cycle depends on the marked seasonality that its fundamental sources of food, *Eudendrium* spp., present in this site. In fact, a large part of the specimens was found in assemblages on *Eudendrium* colonies where large-sized individuals were frequently observed. In particular, since the highest number of *E. pedata* specimens was observed during the winter, we suppose that probably *E. glomeratum* is its favorite prey in this site in a range of depth of 10-15 m. Moreover, in this station *E. pedata* has found good conditions to grow and reproduce (Fig. 4). During 2018, the spawning activity was observed in winter, spring and summer. In 2019, the activity of spawning was seen during the whole year. From 2017 to 2019, *E. pedata* populations increased (Fig. 9) and thus the probability of breeding was higher. This could explain why in 2019 the eggs were present in all seasons (Fig. 3).

In Santa Tecla generally it has been observed the highest number of specimens compared to the other sites. In fact, Santa Tecla is the northernmost of the locations studied and consequently is the first to be influenced by the currents coming from the Strait of Messina (Di Stefano et al., 2013) and bearing veligers and waters rich in nutrients. Therefore, this area could be the site where the majority of *E. pedata* larvae settles and subsequently metamorphoses.

Santa Maria La Scala

As in Santa Tecla, even in Santa Maria La Scala throughout the three years the highest number of *E. pedata,* specimens were observed during the winter. Only in the spring of 2019 the number of specimens reached the same levels of the winter. Consequently, the winter seems to be the favorite season for the settlement of this species, probably due to the presence of *E. glomeratum* also in this site. Nevertheless, contrary to Santa Tecla, this winter abundance of specimens was followed by a drastic decline, probably due to the overgrazing activity on *Eudendrium*. In fact, according to Clark (1975) during population peaks, the overgrazing on arborescent food species causes disappearance of nudibranchs populations, because the food source serves also as microhabitat.

The high number of specimens in spring 2019 could be explained by allochthonously-produced larvae. In fact, according to Clark (1975), the sudden appearances of populations are due to the arrival of large numbers of larvae, that is related to critical temperatures that stimulate settling and metamorphosis.

In figure 7, it can be observed that in 2017 and 2018 there are two different trends throughout the year, which show a remarkable difference between winter and the other seasons. Only during 2019, there was another trend in summer, that is intermediate between winter-spring and autumn.

In this site, during 2017, *E. pedata* eggs were found only in summer. In 2018, the spawning activity was observed in winter and spring. Instead in 2019, the spawning activity was observed in winter, summer and autumn. The eggs were laid on *Eudendrium* colonies, but also on red and brown seaweeds. Most of the specimens was found in a range of depth of 7-20 m.

Catania

In Catania there was a completely different situation compared to the other sites (Fig. 10). In fact, throughout the three years, the winter has never been the season with a major number of *E. pedata* specimens. Instead, in 2017 the summer was the season with the highest number of specimens, with a little number of individuals in the other seasons. During 2018, the season with major number of specimens was the spring that was followed by summer in which there was an absence of *E. pedata* specimens. Also, the spring of 2019 presented the major number of *E. pedata* specimens, but with a number of individuals even greater than the previous years.

This instability of *E. pedata*'s seasonality in Catania reflects the instability of the cycle of its preys. In fact, in harbors and in eutrophic waters, *Eudendrium*'s seasonality is strongly modified (Azzini et al., 2003). Catania is the most polluted site among the studied ones, because of the nearby harbor, the presence of sewerage and the coastal exploitation. Therefore, in these waters, since *Eudendrium* spp. are probably present during the whole year, *E. pedata* larvae could settle in any time of the year. Thus, the *E. pedata*'s seasonality with a highest number of individuals in winter, in this site, was not maintained. Moreover, in Catania it was observed the lowest number of individuals throughout the three years, compared to the other sites. This phenomenon could be related to the southernmost position of Catania compared to the other studied sites and thus, Catania is the area which receive the lowest number of *E. pedata* larvae. With regard to *E. pedata* eggs, they were observed only in summer during 2017, in winter and spring during 2018 and, finally, in spring and summer during 2019. The eggs were laid on *Eudendrium* colonies, but also on red and brown seaweeds. Therefore, in Catania during the three years of study, there was not a real seasonality of *E. pedata*, as in the other sites. In this site, most of the specimens were found in a range of depth of 4-15 m

CONCLUSIONS

The aim of this study was to verify if *E. pedata* is a subannual species and to describe its seasonality along the Ionian coasts of Sicily. Through our observations, we found that *E. pedata* generally prefers cold waters, as in the Adriatic Sea (Betti, 2011), but can tolerate also different environmental conditions. In fact, it is an opportunistic species that feeds on different species of hydrozoans. Its subannual cycle can be deduced also for the spawning activity that is present throughout the year. Moreover, through data collection, we observed that probably *Eudendrium pedata* has a life span of maximum three months because changes in the populations happened in every season.

The only station where the seasonality of *E. pedata* was observed was S. Tecla, where there are the most stable environmental conditions and this species presents two trends. On the contrary, Catania is the most polluted and anthropized site and for this reason there is not a real seasonality of this species, which throughout the three years had an irregular trend. Finally, Santa Maria La Scala presents an intermediate situation between Santa Tecla and Catania, showing for the first two years a trend similar to Santa Tecla's, while the third year is different. Therefore, the optimal situation which represents *E. pedata*'s seasonality in the study areas is that observed in S. Tecla, where there is an increase in autumn, a peak in winter and a decrease during spring and summer. Regarding the *E. pedata*'s general demographic trend in all study sites, between 2017 and 2019, there was a strong increase in the number of specimens.

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Amphibians and Reptiles of the Nature Reserve of Pergusa Lake (Enna, Italy), emphasizing Sicilian endemisms

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ABSTRACT A brief survey on the herpetofauna of the Nature Reserve of Pergusa Lake (Enna, Italy) is provided, highlighting the Sicilian endemic taxa. For this protected area, it is confirmed the presence of 12 species, 4 Amphibians and 8 Reptiles, with two strictly Sicilian endemic taxa: *Bufotes siculus* (Stöck, Sicilia, Belfiore, Buckley, Lo Brutto, Lo Valvo et Arculeo, 2008), and *Emys trinacris* Fritz, Fattizzo, Guicking, Tripepi, Pennisi, Lenk, Joger et Wink, 2005, and the siculo-maltese *Discoglossus pictus pictus* Otth, 1837. Data on the habitat preference and other aspects of ecology and conservation of the recognized species are provided. The research especially confirms the ecological and conservation importance of the protected area for the endemic *Bufotes siculus* and *Emys trinacris* due to their significant populations.

KEY WORDS Amphibians, Reptiles, Pergusa Lake, Nature Reserve, faunal list, Ecology, Conservation.

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INTRODUCTION

The study of the Sicilian herpetofauna has a long tradition (Bruno, 1970), although there are only scattered and incomplete data published till the mid-90s. However, especially in the last two decades, several comprehensive studies (e.g., Turrisi & Vaccaro, 1998; Sindaco et al., 2006; Turrisi et al., 2008; Lo Valvo et al., 2017) improved the knowledge of the Sicilian herpetofauna mainly with regard to Regional distribution, albeit the ecological and conservation aspects still remain poorly investigated, with very few monitoring research (Turrisi et al., 2008; Lo Valvo et al., 2017). The herpetofauna of central Sicily is unsatisfactorily known compared with other recently explored Sicilian territories (Turrisi, 1996; Turrisi & Vaccaro, 1998; Turrisi & Vaccaro, 2004a, 2004b; Sindaco et al., 2006; Turrisi et al., 2008; Restivo et al., 2010a, 2010b; Vaccaro & Turrisi, 2010; Lo Valvo et al., 2017) and still await further monitoring research.

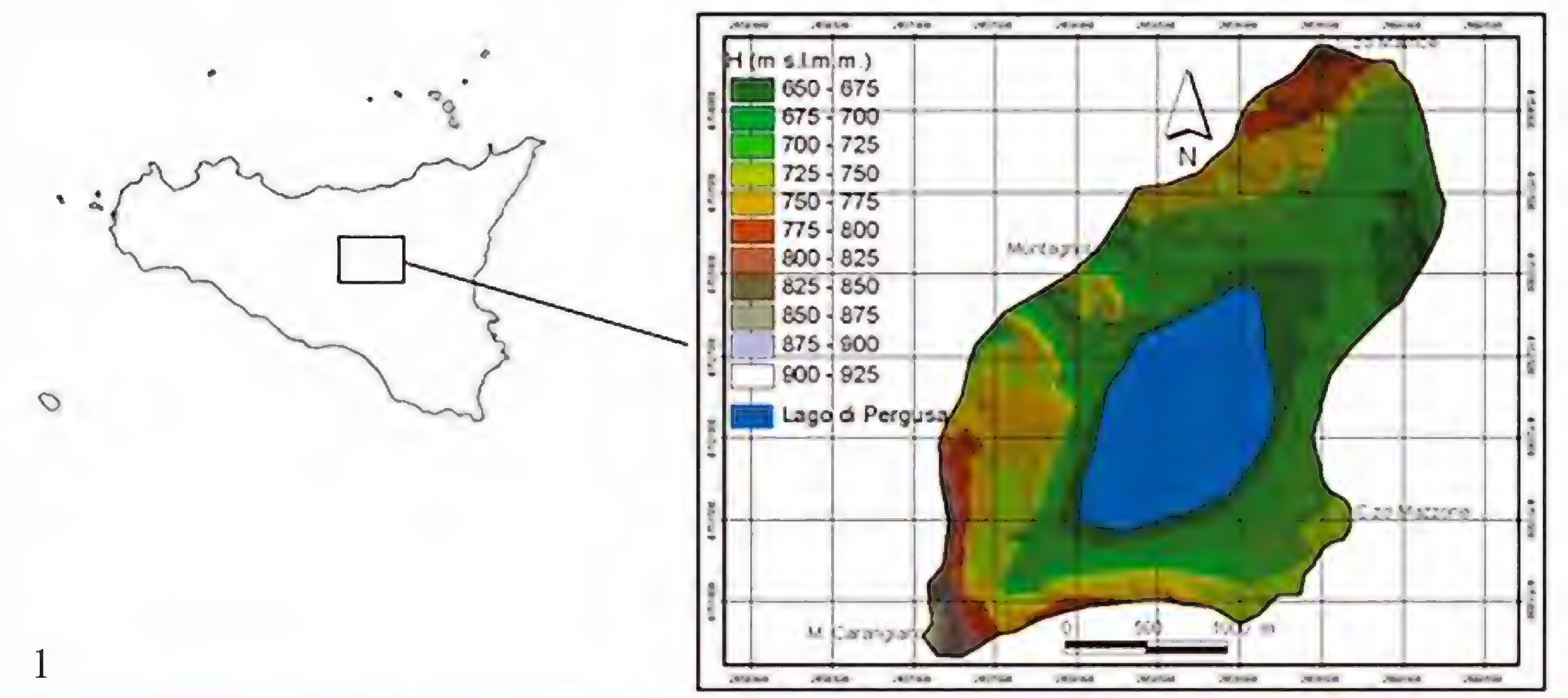
The present paper deals with a brief summary of the herpetofauna of Nature Reserve of Pergusa Lake (Enna, Italy) as an update after the contributions by Turrisi (2004, unpubl.), Termine et al. (2008), and Termine & Turrisi (2016), emphasizing Sicilian endemisms, all of them having close ecological relationships with the water bodies and the riparian area. We also highlight and discuss some conservation aspects as a framework for future monitoring programmes.

We are pleased to dedicate the present paper in honour of an authoritative Naturalist, our friend Prof. Bruno Massa (Palermo), for his great longtime efforts to the knowledge and protection of the biodiversity of Sicily.

MATERIAL AND METHODS

Study area

The Nature Reserve “Lago di Pergusa” (Figs. 1-2) is located in central Sicily (667 m a.s.l.) and is managed by “Libero Consorzio Comunale di Enna”. This protected area covers 402,5 ha and represents a rare example of natural Sicilian endorheic lake (Grasso et al., 2003); its average water salinity has been 7.3 ppt in 2014 (Termine, 2015, unpubl.). It is also included in the network Natura 2000 as core breeding and resting site for rare and threatened species, and some rare natural habitat types which are protected in their own right (Termine et al., 2008).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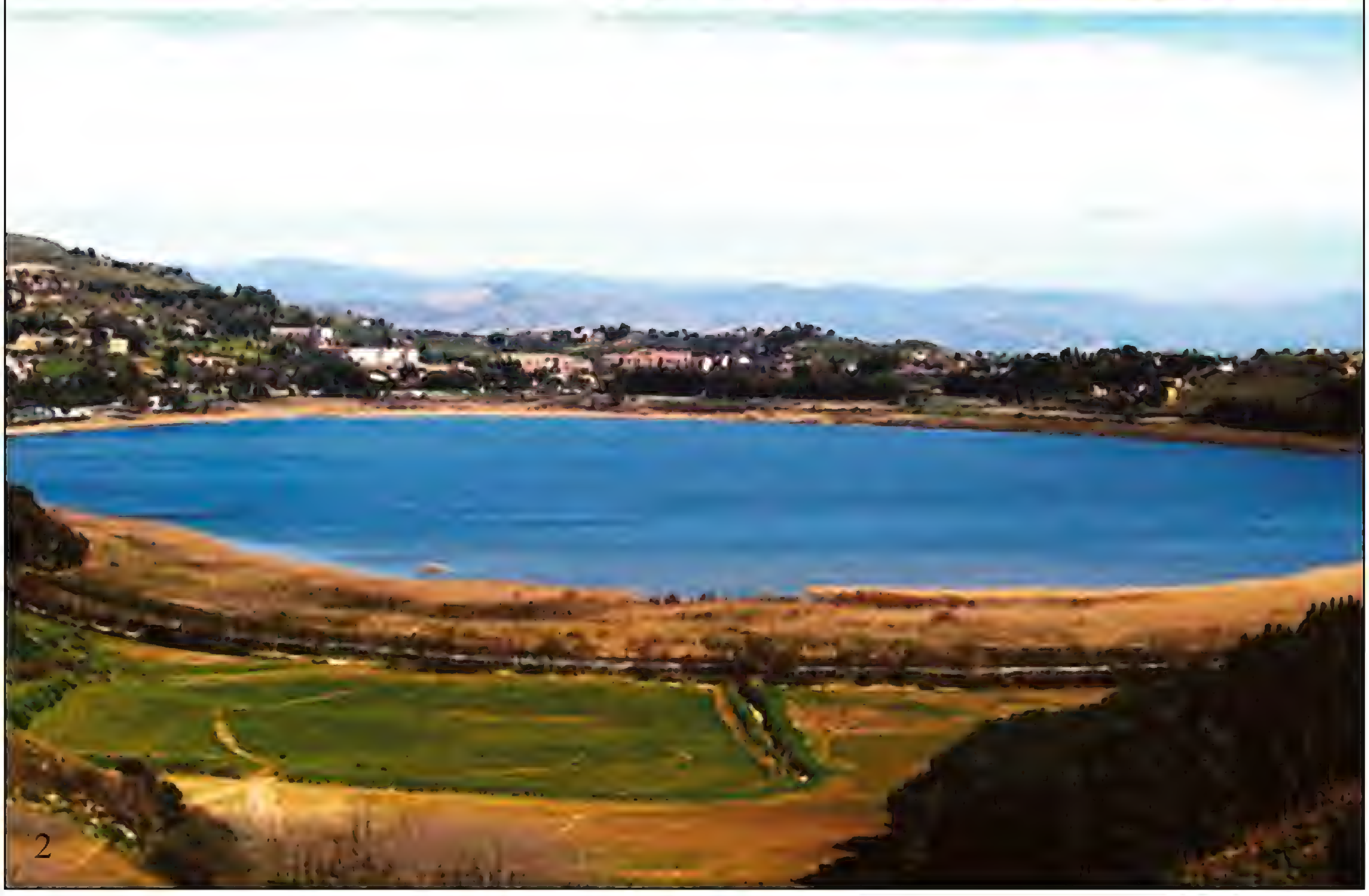

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Figure 1. Study area (map elaborated by Elena Amore, 2005). Figure 2. View of Pergusa Lake (Enna).

Sources and data treatment

Based on a monitoring plan of more than twenty years (1996-2019), the faunistic presence of both amphibians and reptiles in the study area is updated, emphasizing three herpetological endemisms. Their presence has been evaluated in detail with regard to phenology, habitat preference, estimate population size and breeding sites. The investigations have been carried out through direct observations of specimens, eggs, larvae, clutches, and song signals. The data were stored in a database for further elaboration, and have been added to the Sicilian Herpetological Database (Turrisi & Vaccaro, ongoing) to update the Sicilian Herpetological Atlas (Turrisi et al., 2008). The systematic account follows the recent checklist of the European herpetofauna (Speybroeck et al. (2020), although we still consider *Bufotes siculus* (Stöck, Sicilia, Belfiore, Buckley, Lo Brutto, Lo Valvo, Arculeo, 2008) at a full species rank instead of subspecies of *B. boulengeri*, as documented and supported by Colliard et al. (2010).

RESULTS

Faunistic account

Our research shows that Pergusa Lake is a hotspot of herpetological diversity in the context of central Sicily, including 12 species, 4 Amphibians and 8 Reptiles (Table 1), with two strictly interesting Sicilian endemic taxa: *Bufotes siculus*, and *Emys trinacris* (Turrisi, 2004, unpubl.; Termine, 2006a; Termine et al., 2008). We also still consider *Discoglossus pictus pictus* as valid subspecies, a putative siculo-maltese endemism (Turrisi et al., 2008), since it has been confirmed as a distinct genetic lineage, although weakly differentiated from the other subspecies, *D. pictus auritus* Héron-Royer, 1888 (Zangari et al., 2006), distributed in Tunisia and Algeria (introduced in Spain and southern France), and thus having a significant biogeographic and conservation interest (Turrisi & Vaccaro, 1998; Turrisi, 2008a). *Hyla intermedia* Boulenger, 1882 is recorded for "Pergusa" by Bruno (1970), but it has not been confirmed, and it is presently excluded from the checklist.

The Sicilian endemisms

Three Sicilian endemic or sub-endemic taxa are recorded in the study area.

The Painted Frog, *Discoglossus pictus* (Fig. 3) has a West Mediterranean distribution pattern being present in North Africa (Algeria and Tunisia), Italy (Sicily), and Maltese Islands (Malta and Gozo) (Stöck et al., 2015). It is widespread in Sicily with some deficient data for central and southern parts (Turrisi, 2008a; Lillo et al., 2013; Lo Valvo et al., 2017). Ecological preferences, shows that it is frequent along the riparian area of the lake, and in some small ponds around the lake (Turrisi, 2004 unpubl.; Termine et al., 2008). The main breeding sites occur in a narrow peripheral side of the lake, where the body water is not deep and partly covered by vegetation. We highlighted almost regular breeding and migratory events for *Discoglossus pictus pictus*, which during March-October shows a number of specimens (mostly neo-metamorphosed) around the lakeside.

The Sicilian Green Toad, *Bufotes siculus* (Fig. 4), has a north-African origin (having as sister clade *B. boulengeri* Lataste, 1879), and occupies the western and southern parts of Sicily (with some de-

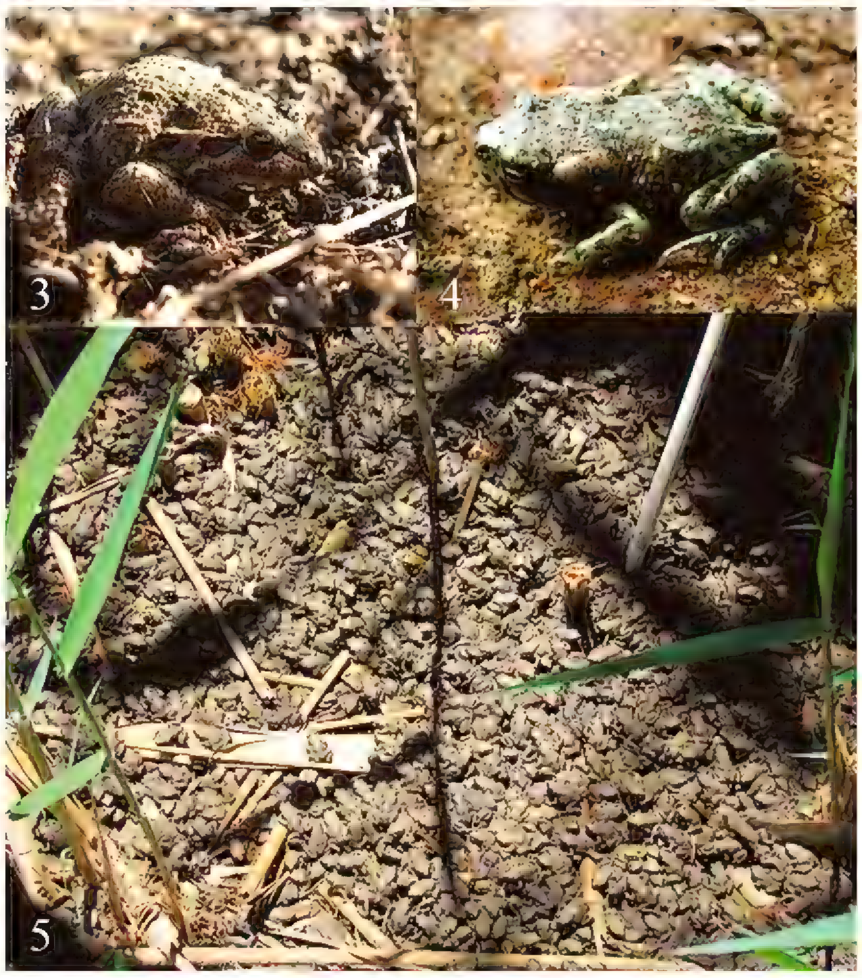


Figure 3. *Discoglossus pictus pictus*, adult. Figure 4. *Bufotes siculus*, subadult. Figure 5. Massive aggregation of *Bufotes siculus*.

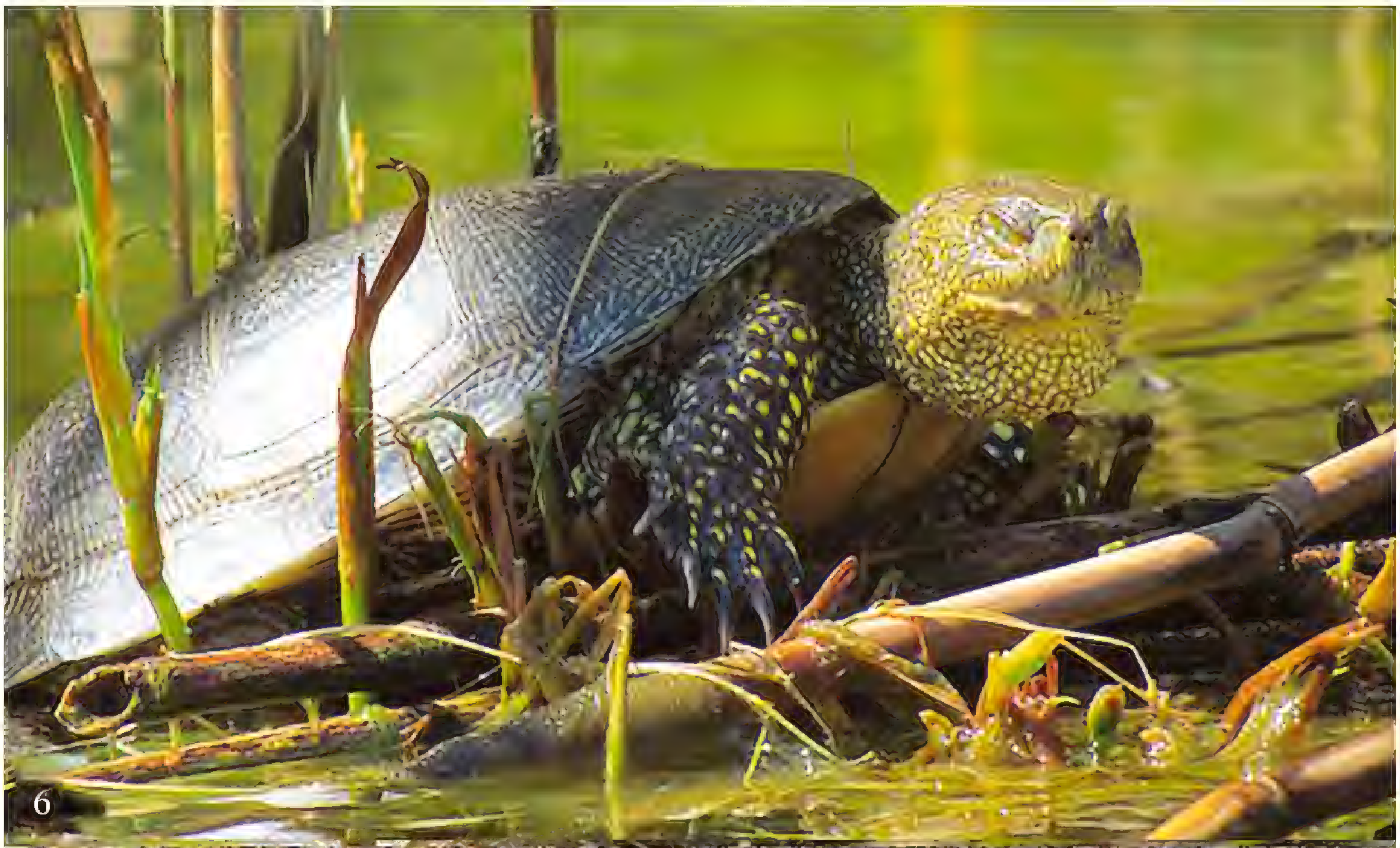
ficient data in the remaining territories), as well as two small islands off the north-western coasts (Ustica and Favignana) (Stöck et al., 2008; Sicilia, 2008; Colliard et al., 2010; Lo Valvo et al., 2017). It is very common and abundant in the study area. Most of the breeding sites are included in a narrow part of outer lake, where the body water is not deep and partly covered by vegetation. We highlighted almost regular explosive breeding and migratory events (Fig. 5) during May-August, for 1 to 6 weeks, with very high population density around the lakeside (estimated 50-400 specimens/m^2), including mostly neo-metamorphosed mixed-up with a small number of specimens of *Discoglossus pictus pictus*. According to our data, in the late spring of 1996 a huge explosive breeding and migratory event was documented, whereas in the subsequent years, up to 2002, no relevant observations have been done; from 2003 to-date, several explosive presences of this taxon have been regularly observed.

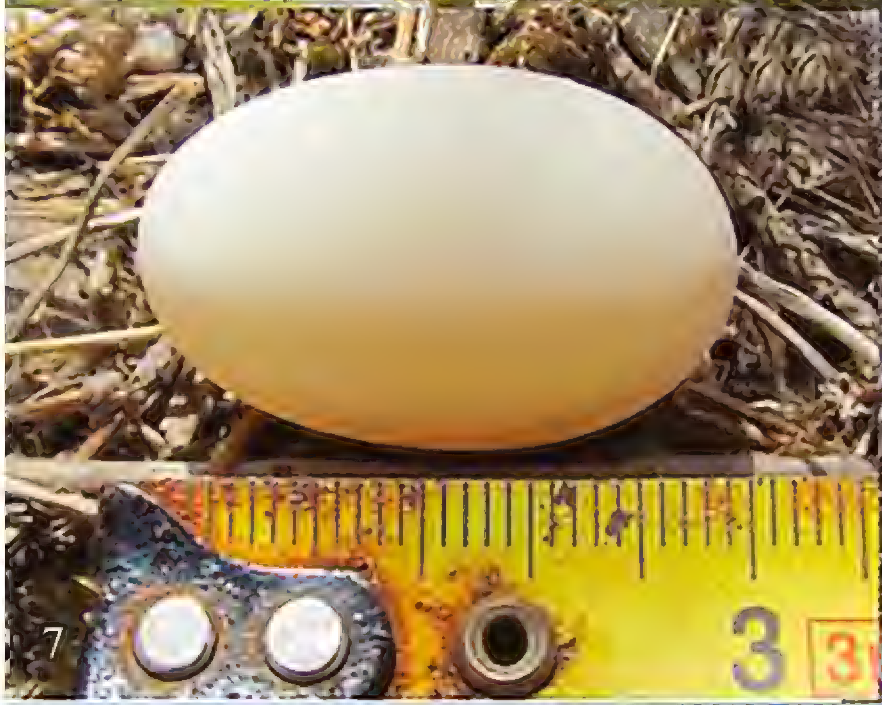
The Sicilian Pond Turtle, *Emys trinacris* (Fig. 6), has a widespread but fragmentary distribution in Sicily mainland, especially in the north and central parts (Turrisi, 2008b; Di Cerbo, 2010). Pergusa Lake is currently one of the most important breeding site for *E. trinacris* in central Sicily, with regular observations of specimens during basking, foraging, migration and nesting. The first detection was on 29.IV.2005 of an adult male, after the increasing of the lake water level, started on 2003. Previously, from the late ‘80s to 2002, *Emys trinacris* abandoned the main site to populate alternative neighbouring wet sites, e.g., one pond located on a south-west hill, since Pergusa Lake became almost drained, with very high degree of salinity (values more than 70 ppt registered in July 2002 according to Termine, 2006b). Several observations over the subsequent six-years period corroborate the presence of a stable reproductive population, as summarized and detailed in the following. The first oviposition was directly observed on 02.VIII.2014 in the east side of the lake (37°30’57,35”N; 14°18’46,25”E), in an open and sloping area, at about 5 m from the lakeshore; in the same day, close to this nest, a holed nest was observed, destroyed by an unidentified predator, containing mixed-up broken eggs and one entire egg (length/width: 29/18 mm) (Figs 7, 8). An adult male (carapace length/width: 155/115 mm) has been observed on 16.VI.2015 while walking over car tracks (37°31’18,96”N; 14°18’33,10”E), at about 60 meters from the lake border. Another specimen has been observed during oviposition on 13.VII.2016 in the same river (37°30’57,71”N; 14° 18’46,29”E), about six meters far from the water and 11 meters far from the previous oviposition site. In the same day, at about 30 meters far from the latter oviposition site (37°30’58,67”N; 14°18’46,36”E), a holed nest has been observed, closely bearing fecal rest probably of the Red Fox, *Vulpes vulpes* Linnaeus, 1758. Two just hatched juveniles (Fig. 9) have been observed on 11.IV.2017 (carapace length/width: 27/17 mm; plastron length/width: 24/17 mm), in the north side of the lake (37°31’12,72”N; 14°18’24,75”E) while reaching the water; in the same place a male has previously been observed on 14.III.2017 (carapace length/width: 152/112 mm; plastron length/width: 130/72 mm). Two different predations have been documented, respectively on 28.VII.2017 (37°30’55,51”N; 14°18’45,94”E) and 16.VIII.2017 (37°30’56,02”N; 14°18’46,05”E) along the river. Until recently, an adult male (carapace length/width: 142/103 mm) has been observed on 12.VI.2018 along the west river (37°30’49,36”N; 14°18’0,13”E). Another holed nest has been observed on 10.VII.2018 along the east river (37°31’0,00”N; 14°18’46,28”E). Finally, a predation case has been documented on 06.VI.2019 along the east river (27°30’54,84”N; 14°18’46,02”E), close to the previous documented cases.

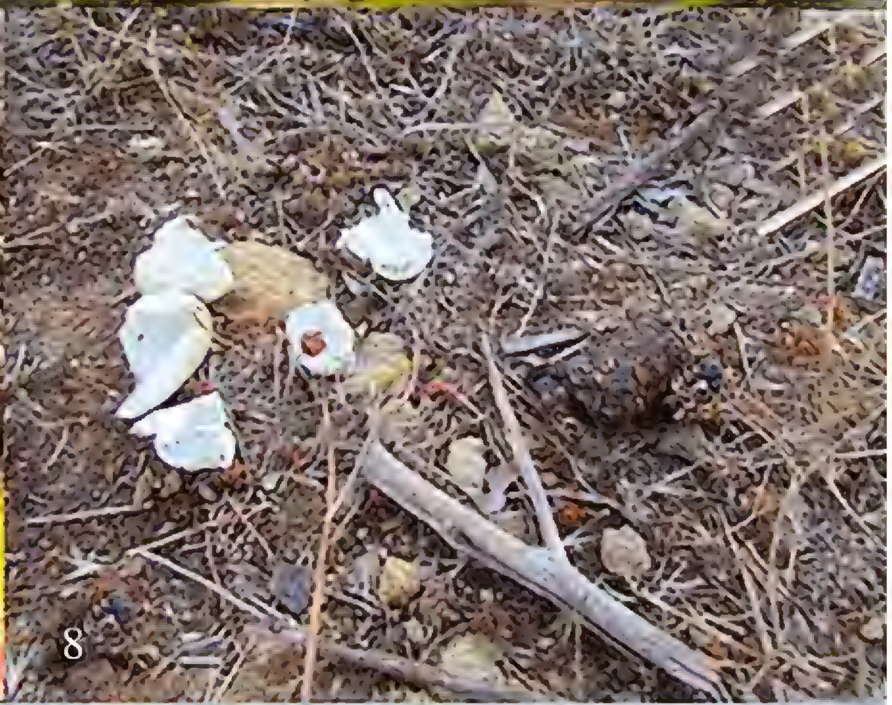
In Pergusa Lake, *Emys trinacris* basking takes place along the lakeside or on floating substrates built by *Porphyrio porphyrio* (Linnaeus, 1758) with *Phragmites australis* (Cav.) Trin. ex Steud. stems (Termine, 2014); a maximum of three specimens has been observed in the same place.

CONCLUSIONS

The data accumulated until now put in evidence that the three endemic Sicilian herpetological taxa, two amphibians and one reptile have significant populations in Pergusa Lake, with moderately to high population-density and widespread local distribution. The conservation status of all the three taxa can be currently considered satisfactory enough, although exposed to some significant anthropogenic disturbance. For







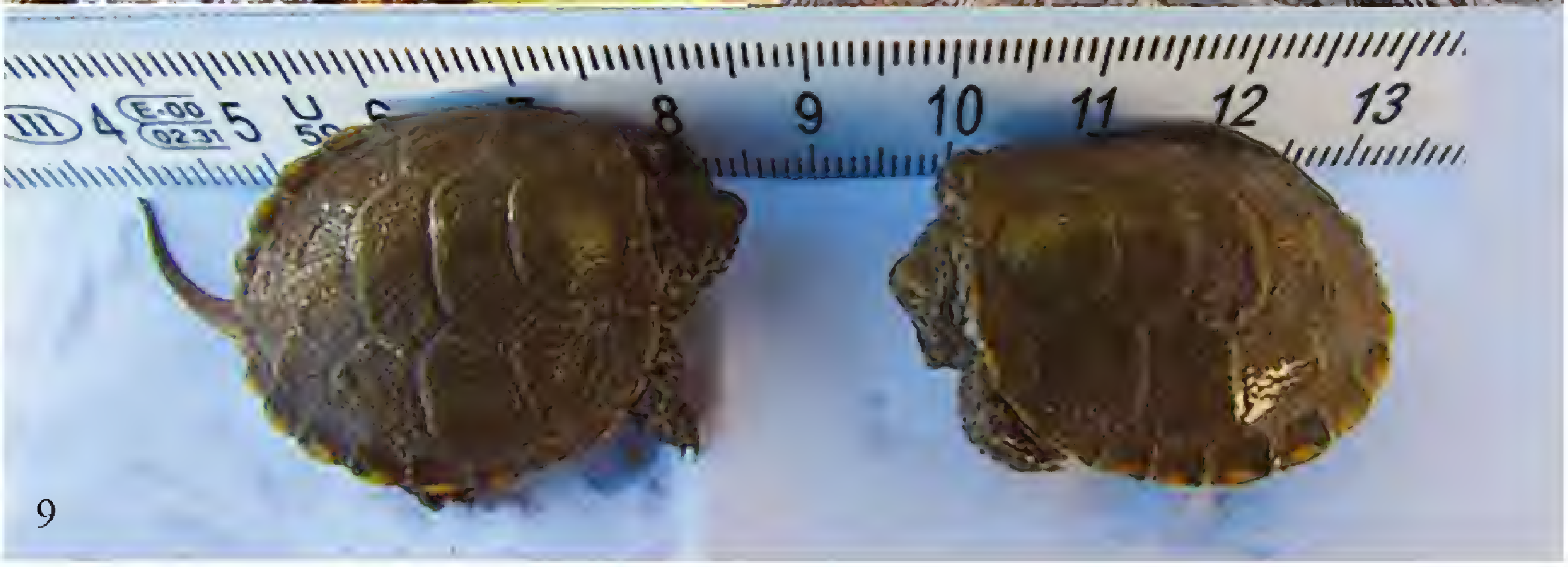


Figure 6. *Emys trinacris*, adult. Figure 7. *Emys trinacris* egg. Figure 8. *Emys trinacris*, holed nest after predation (on the right, fecal rest possibly of *Vulpes vulpes*). Figure 9. *Emys trinacris*, hatchlings.

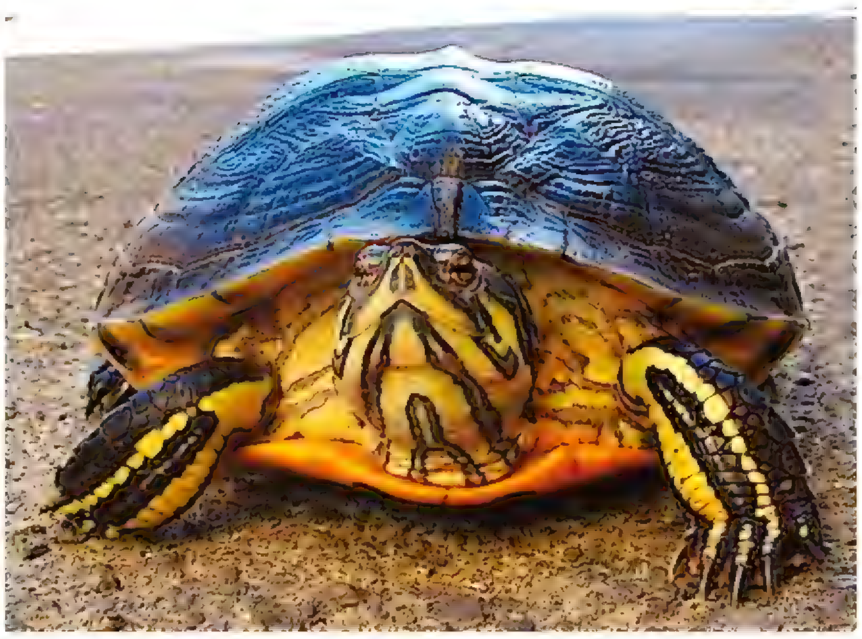


Figure 10. *Trachemys scripta*, adult.

instance, the presence of the autodrome around the Lake, although its use is under some restrictions, as well as of a peripheral public road close to the autodrome, represent remarkable and serious ecological problems, affecting the conservation status especially of amphibians, due to their explosive migratory and breeding behaviour, with frequent, significant road-killing events. This suggests that effective under-road passages should be built in order to mitigate this problem (Turrisi, 2004 unpubl.; Termine et al., 2008).

In Sicily, the presence of the allochthon *Trachemys scripta* (Schoepff, 1792) (Fig. 10) has been detected several times (Bella & Turrisi, 2005; Lillo, 2008) with two subspecies *T. scripta elegans* (Wied, 1839) and *T. scripta troosti* (Holbrook, 1836) being represented in the site. The first detection in the area was in San Giovannello, in an artificial body water on 24.VII.2004 (G.F. Turrisi, pers. obs.). Further detection was on 10.III.2006, with observation of an adult specimen in the north side of the lake, on Razza Pier. Subsequently, additional records confirmed the presence of the two-above-mentioned subspecies, with several specimens observed along the autodrome, in the east and south-east sides of the lake; some specimens were collected and delivered to the local Forestry Authority and subsequently to the Wildlife Recovery Center of Ronza, Piazza Armerina, Enna. Very recently, an egg-bearing female was induced to lay artificially by injection of oxytocin, thus confirming that this alien species is able to develop eggs and thus, possibly to reproduce in the site (Liuzzo et al., 2020). The presence of the *T. scripta* suggests the need of careful monitoring programme for possible ecological impacts on indigenous communities, and especially for possible competition with the endemic *Emys trinacris*, currently not well understood.

The presence and the relative extension of wetland and water bodies of Sicily is of primary importance especially for amphibians and aquatic avifauna, and their role have been recently highlighted by Sarà et al. (2011). The data shown demonstrates how the Nature Reserve of Pergusa Lake is important for the conservation not only of birds (Termine et al., 2008) and biodiversity as a whole, but also with regards to herpetological taxa living in wet ecosystems, and how minimal anthropogenic interventions can perturb natural characters. The physiographic features, and the host of a high biodiversity (Termine et al., 2008), make this ecosystem unique and precious in the Sicilian context and allow us to understand the enormous potential that it could have in the Mediterranean framework for the protection of biodiversity.

Our results emphasize the need for considering functional aspects of the ecological traits of the herpetological fauna, to improve management actions for conservation strategies, especially of the Sicilian endemic taxa, in order to preserve both diversity and ecosystem functioning.

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Stranding of *Balaenoptera acutorostrata* Lacépède, 1804 (Mammalia Cetacea) on the coast of Fregene (Rome, Latium, Italy)

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ABSTRACT The stranding of a juvenile of Minke Whale (*Balaenoptera acutorostrata* Lacépède, 1804) on the coast of Fregene, near Rome (Latium, Central Italy) is here reported. Historical and recent data suggest the possibility that the Mediterranean Sea could be a potential birth or nursery area for this species.

KEY WORDS Cetacea; Balaenopteridae; stranding; Tyrrhenian Sea; Fregene.

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INTRODUCTION

The Minke Whale (*Balaenoptera acutorostrata* Lacépède, 1804) is a cosmopolitan species found in all oceans and at all latitudes, from 65° S to 80° N. (Stewart & Leatherwood, 1985; Arnold et al., 1987; Arnold, 1997). The Minke Whale is a species listed in the Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora - CITES (except for the population of West Greenland listed in Appendix II) and it is considered a "threatened species" in the Annex II of the Barcelona Convention for Protection against Pollution in the Mediterranean Sea. This species is also included in the Appendix II of the Bern Convention on the Conservation of European Wildlife and Natural Habitats and considered a "*Strictly protected fauna species*". It is also a "species in need of strict protection" in the European Union by the Annex IV of the Council Directive 92/43/EEC of May 21th 1992 on the conservation of natural habitats and of wild fauna and flora, known as "Habitats Directive". Finally, it is listed as "Vulnerable" at the European level, and classified as "Least Concern" on the IUCN Red List of Threatened Species (Reilly et al., 2008; Maio et al., 2016). In the Mediterranean Sea, according to the Annex 4 of Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), this species is considered as a "*visitor species*", "*occasional*" in the Italian seas (Maio et al., 2016).

Balaenoptera acutorostrata has a stockier build than the other species of the Balaenopteridae family, with a triangular head and a narrow, pointed muzzle. The dorsal fin is larger than that of *B. bonaerensis* and is placed in a more advanced position, the pectoral fins are small and lanceolate, and the caudal fin is wide. The coloring of the upper parts is slate gray or dark gray, that of the lower parts is whitish; the dorsal part of the pectoral fins is crossed by a white band. The adults of the northern oceans have an average length of 7/9 meters and a weight of almost 5 tons.

MATERIAL AND METHODS

Fregene, in the Municipality of Fiumicino just 30 km from Rome in Latium, is a well-known seaside village in the Tyrrhenian Sea. The coordinates are: 41°51'11.08"N - 12°11'36.16"E. The presence of the mouth of the Arrone River, emissary of Bracciano Lake, is significant in the area for the inputs of nutrients and debris at sea. The village of Fregene is part of the Agro Romano area. The whale beaching took place on April 26th 2020, in the area overlooking the "Glauco" beach property. The authorities were notified of the presence of a large cetacean stranding on the beach (Fig. 1). The animal was found to be a juvenile female specimen of *B. acutorostrata*, 2.5 meters long. An evident prolapse of the tongue, already swollen by the progress of the decomposition process, indicated that, probably, the animal had arrived ashore already dead (Figs. 2, 3). Currently the causes of death have not been disclosed by the Experimental Zooprophylactic Institute of Latium and Tuscany, which collected biological samples for the analyses required in these cases. The specimen in question could probably be the same that was spotted only a few days earlier inside the harbor of Anzio, on the southern Latium coast.

RESULTS

Systematics

Classis MAMMALIA Linnaeus, 1758
Ordo CETACEA Brisson, 1762
Subordo MYSTICETI Cope, 1891
Familia BALAENOPTERIDAE
Genus *Balaenoptera* Lacépède, 1804

Balaenoptera acutorostrata Lacépède, 1804

The historical data from 1771 to 2016 revealed 49 records of stranded or caught *B. acutorostrata* in the Mediterranean Sea (Cagnolaro et al., 2014).

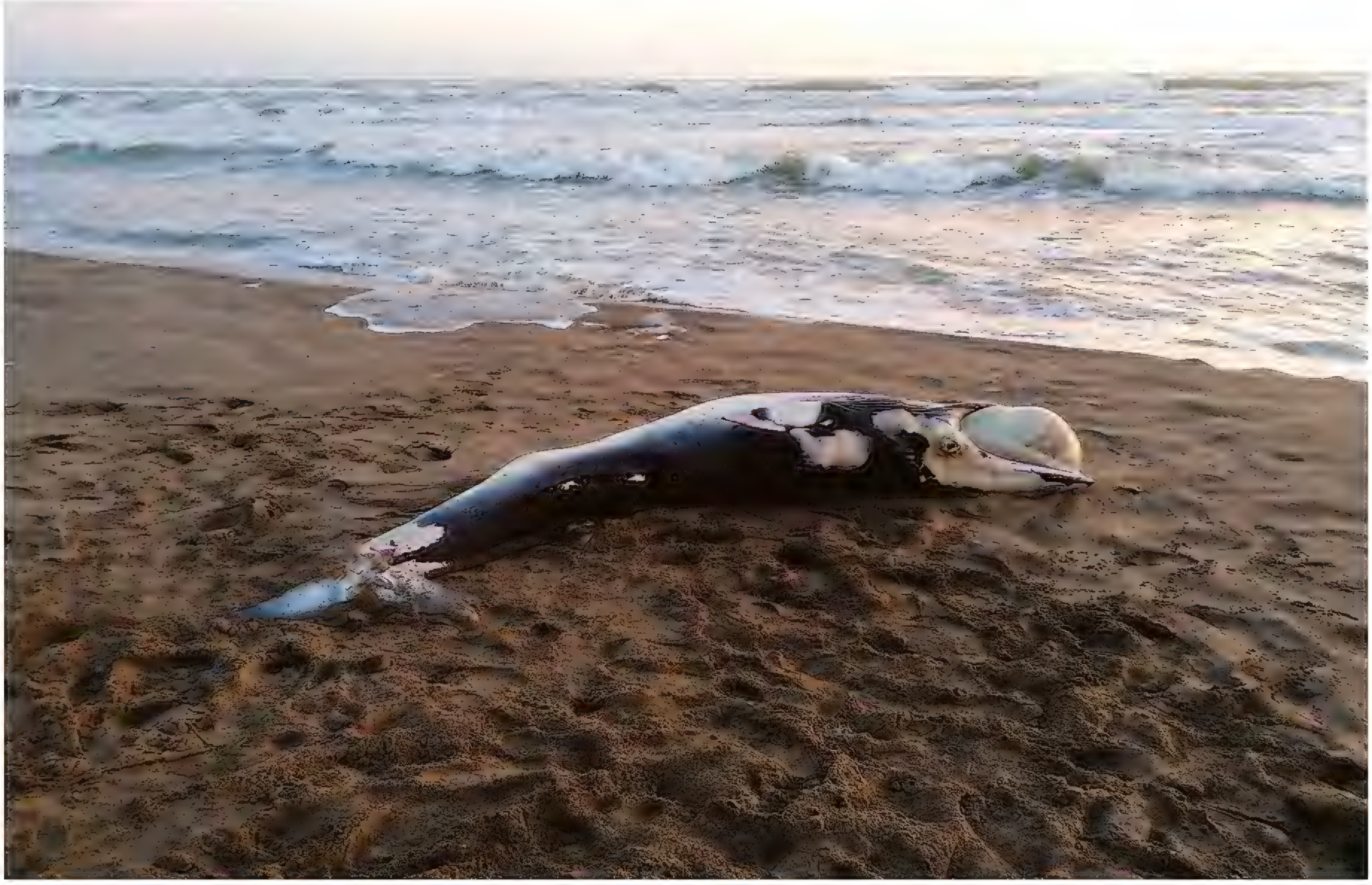
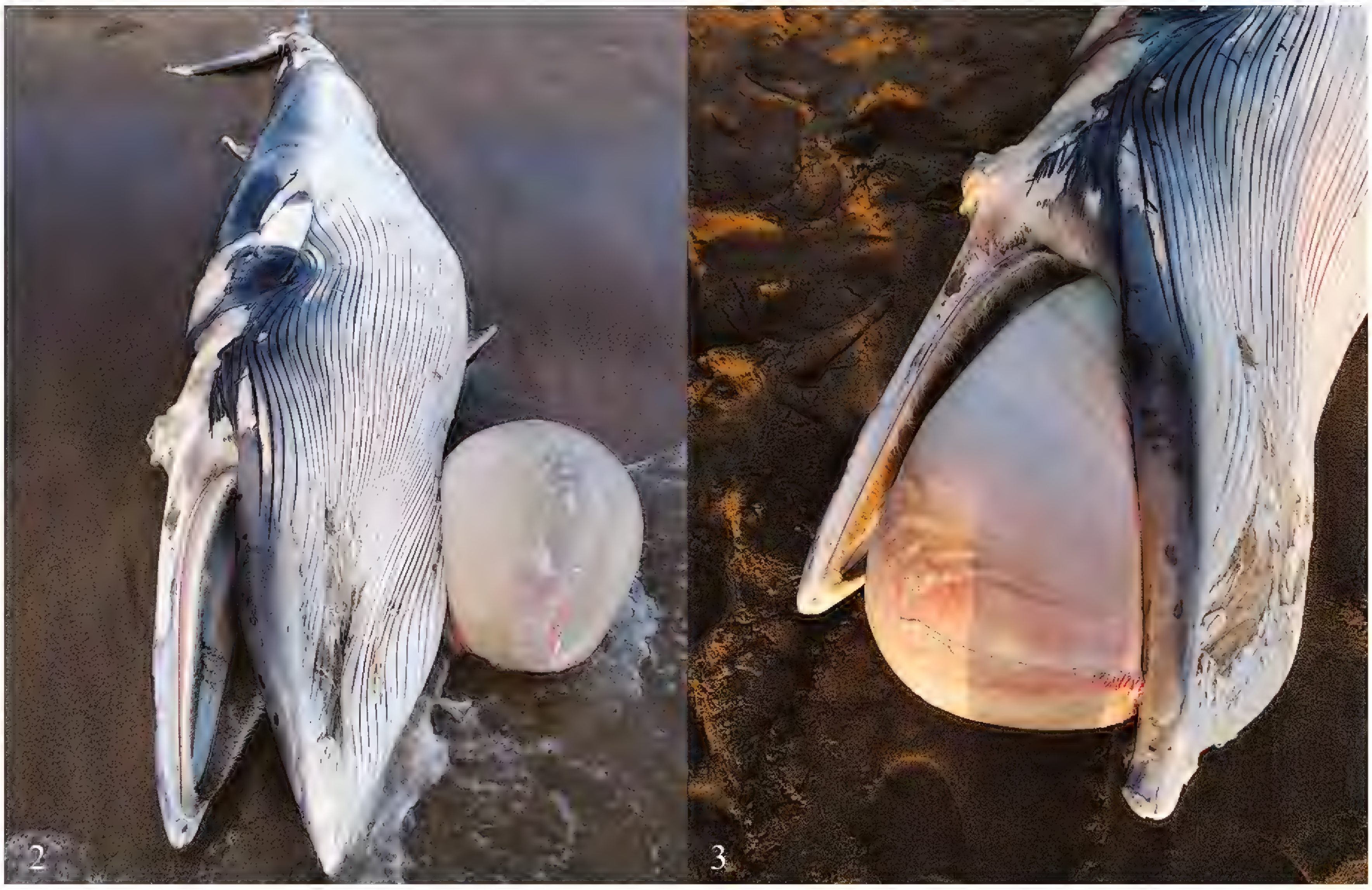


Figure 1. *Balaenoptera acutorostrata* on ther coast of Fregene (Thyrrenian Sea, Italy).



Figures 2, 3. *Balaenoptera acutorostrata* on ther coast of Fregene (Thyrrenian Sea, Italy).

Fifteen of the 49 records were represented by young individuals, less than 4 meters long (Maio et al., 2016). Mitochondrial DNA analyses performed on a young specimens of the same species stranded in 2010 on the Salerno coast revealed that the whale had a haplotype identical to that of the North Atlantic populations (Maio et al., 2016). This data, also supported by the significant share of young specimens that have been found in the Mediterranean Sea, suggests that our seas are likely to be used to give birth and as a nursery area to the lesser whales of the Atlantic.

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